REPORT RESUMES

ED 003 479 24
RESISTIVE EXERCISES IN THE DEVELOPMENT OF MUSCULAR STRENGTH AND ENDURANCE.
BY- MCCRAW, LYNN W. BURNHAM, STAN
TEXAS UNIV., AUSTIN
REPORT NUMBER CRP-1979 PUB DATE 63
EDRS PRICE MF-$0.18 HC-$4.28 107P.

DESCRIPTORS- *PHYSICAL EDUCATION, PHYSICAL ACTIVITIES, PHYSICAL FITNESS, *COLLEGE STUDENTS, *PERFORMANCE, PERFORMANCE FACTORS, AUSTIN, TEXAS

A STUDY WAS CONCERNED WITH A COMPARISON OF ISOTONIC, ISOMETRIC, AND SPEED EXERCISE PROGRAMS AS A MEANS OF DEVELOPING MUSCLE STRENGTH, ENDURANCE, SPEED, AND POWER. SUBJECTS FOR THE INVESTIGATION WERE 93 FRESHMEN AND SOPHOMORE MEN ENROLLED IN A PHYSICAL EDUCATION CLASS. AFTER MEASUREMENT OF INITIAL STATUS IN THE ATTRIBUTES UNDER CONSIDERATION, THE SUBJECTS ENGAGED IN THE APPROPRIATE PROGRAMS THREE TIMES A WEEK FOR 9 WEEKS. MEASUREMENT OF FINAL STATUS WAS MADE USING THE SAME INSTRUMENTS AS WERE USED TO DETERMINE INITIAL STATUS. DATA WERE ANALYZED AND THE RESULTS PROVIDED THE BASIS FOR THESE CONCLUSIONS--(1) NO SINGLE METHOD WAS ADEQUATE IN ACHIEVING MAXIMUM DEVELOPMENT OF ALL FOUR ATTRIBUTES (STRENGTH, ENDURANCE, SPEED, AND POWER OF THE MUSCLES), (2) THE EXTENT TO WHICH A PARTICULAR METHOD IS EFFECTIVE MAY DEPEND ON THE INITIAL STATUS OF THE INDIVIDUAL IN THE ATTRIBUTE IN QUESTION, (3) THE ISOTONIC AND ISOMETRIC METHODS APPEARED TO BE BEST FOR DEVELOPING STRENGTH FOR PERSONS WHO ARE INITIALLY STRONG, (4) RESISTIVE EXERCISES DID NOT APPRECIABLY AFFECT SPEED OF THE MUSCLE, (5) ISOTONIC AND SPEED MOVEMENTS WERE MORE EFFECTIVE THAN ISOMETRIC CONTRACTIONS IN IMPROVING EXPLOSIVE POWER FOR INDIVIDUALS ALREADY POSSESSING SOME OF THIS ATTRIBUTE. IMPLICATIONS FOR FURTHER RESEARCH WERE PRESENTED. (JC)

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Office of Education
This document has been reproduced exactly as received from the person or organization originating it. Points of view or opinions stated do not necessarily represent official Office of Education position or policy.

RESISTIVE EXERCISES IN THE DEVELOPMENT OF MUSCULAR STRENGTH AND ENDURANCE

Cooperative Research Project No. 1979

Lynn W. McCraw, Principal Investigator
Stan Burnham, Associate Director

The University of Texas
Austin, Texas
1963

The research reported herein was supported by the Cooperative Research Program of the Office of Education, U. S. Department of Health, Education, and Welfare.

ED 003479

ACKNOWLEDGMENTS

Appreciation is extended to the many persons who cooperated in conducting this study. The authors wish to thank particularly Carson McGuire, Director, Research in Education, for assistance in designing the project and for suggestions relative to collecting and analyzing the data. Thanks are expressed also to Earl Jennings and Ray Whiteside of the Department of Educational Psychology and Laboratory of Human Behavior for assistance in using the multiple linear regression technique and in preparing computer programs. Special acknowledgment is due Thomas Edward Barlow, Director of Required Physical Education for Men, for providing students to serve as subjects and facilities for the exercise programs. For collecting data and conducting resistive exercises, thanks are expressed to physical education students Armando Chapa, Ned Cole, Richard Stark and Kenneth Gilmore. The latter also assisted in analyzing data. The authors are especially grateful to Shirley Gallaher for typing the manuscript.

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS ii

I. NATURE OF THE STUDY 1

  Purpose 2
  Subjects 3
  Background 4

    Strength 6
    Endurance 13
    Speed 20
    Power 25
    Summary 28

II. PROCEDURE 29

  Testing Procedures 29

    Strength Tests 30
    Speed Tests 32
    Endurance Tests 34
    Power Tests 35

  Exercise Programs 46

    Isotonic Exercises 47
    Isometric Exercises 50
    Speed Exercises 53

III. FINDINGS 56

  Comparison of Treatment Effects 56

    Multiple Linear Regression Technique 56
    Results of Analysis 62
    Discussion 69

  Adaptation of Methods 88

IV. CONCLUSIONS AND IMPLICATIONS 91

V. REFERENCES 94

LIST OF TABLES

Table Page

1. Means and Standard Deviations for the Isotonic Group 70
2. Means and Standard Deviations for the Isometric Group . . . 71
3. Means and Standard Deviations for the Speed Group 72
4. F-Ratios for Strength 73
5. F-Ratios for Speed 74
6. F-Ratios for Endurance 75
7. F-Ratios for Power 76

LIST OF FIGURES

Figure Page

1. Cable Tensiometer 38
2. Strength Table 38
3. Arm Strength Test 39
4. Leg Strength Test 39
5. Electric Chronoscope 40
6. Arm Speed 40
7. Leg Speed 41
8. Starting Speed 41
9. Arm Endurance (Starting Position) 42
10. Arm Endurance (Movement Position) 42
11. Leg Endurance Test 43
12. Jump and Reach Board 43
13. Leg Power Test (Measuring Position) 44
14. Leg Power Test (Jumping Position) 44
15. Arm Power Test (Starting Position) 45
16. Arm Power Test (Movement Position) 45
17-28. Illustrations of Sample Regression Lines 63
29. Flow Chart for Computation of F-Ratios 65

Figure Page

30. Regression Lines for Arm Strength 77

31. Regression Lines for Leg Strength 78

32. Regression Lines for Arm Speed 79

33. Regression Lines for Leg Speed 80

34. Regression Lines for Starting Speed 81

35. Regression Lines for Arm Endurance 82

36. Regression Lines for Leg Endurance 83

37. Regression Lines for Arm Power 84

38. Regression Lines for Leg Power 85

RESISTIVE EXERCISES IN THE DEVELOPMENT
OF MUSCULAR STRENGTH AND ENDURANCE

I. NATURE OF THE STUDY

Coaches of interschool athletics and teachers of physical education almost universally today use resistive exercises as a means of conditioning individuals for participation in physical activities. This practice is based on the concept that strength is fundamental to performance in sports and other physical education activities and that the muscles must be subjected to resistance in order to develop sufficient strength. Such beliefs are not new, for the Greeks as early as 700 B.C. routinely used weights tied to the arms and legs in training for events in the Olympic and other meets. Furthermore, the emphasis on strength testing in this country during the latter part of the 19th Century indicates that many persons believed that the athlete should be strong. With the classic research by Morpurgo (58:147) in 1897 came the acceptance of the fact that the muscle must be subjected to the overload in order to improve strength to the maximum.

Only those interested in the art of weight lifting made immediate application of the results by Morpurgo. The emphasis here, however, was in developing strength so as to improve performance in weight lifting itself, rather than to ensure success in sports and other activities. There was a prevailing belief that the use of weights would cause an individual to become muscle bound and thus deter rather than enhance his performance. Since 1945 this concept has gradually changed because of numerous research studies and through the enterprising efforts of a few coaches in trying out new ideas. More recent studies by Muller (45:41-47), have directed attention to isometric contraction whereby the muscle contracts momentarily without movement against the overload.

Much has been learned, both from research and practical experience, about the development of the strength of the muscles and the importance of this strength in performance in physical activities. Many unanswered questions remain, however, particularly with regard to the most effective method to use. For example, to what extent does isometric contraction increase the endurance of the muscles as well as its strength? Also, how rapidly should the muscle move against resistance? Most studies have dealt with how much, how long, and how often the muscle should contract against resistance with little or no attention given to how swiftly it should move. Finally, which of the resistive methods can be adapted most easily for use in a practical situation. To obtain answers for these and other questions, much research is needed.

Purpose

The purpose of this investigation is to determine the effectiveness of three methods of resistive exercises in increasing muscular strength and endurance and in improving performance in physical activity. The study is concerned also with possible modifications of the methods so as to make them more applicable to a practical situation. The three resistive methods are:

1. Isotonic method. The subject lifts weights repeatedly at a moderate rate of speed. Weights are added as strength is increased.

2. Isometric method. The subject exerts a maximum contraction for 5 to 10 seconds without movement of the muscles.

3. Speed method. The subject contracts muscle groups quite rapidly using relatively light weights or against resistance provided by the body itself.

The speed and power of muscle contraction are used as the measure of performance in physical activity. Data on speed and power as well as strength and endurance of the muscles were obtained from a pre-test and a post-test administered at the beginning and end of the study. All tests involved the same muscle groups performing essentially the same body movements. These movements are as follows:

1. Arm flexion and forearm extension.
2. Thigh extension and leg extension.

Subjects

The subjects for the investigation consisted of 93 freshmen and sophomore men enrolled in required physical education classes at The University of Texas. Each person volunteered to participate in the study, and insofar as could be determined, each one was satisfied with the exercise regime that he followed. The subjects were placed in the resistive programs by random selection. The three groups were reasonably well equated on the basis of age, height, and weight. Only those subjects who continued the exercises throughout the study and completed all tests were included in the analysis.

Background

During the past decade interest has increased in the scientific application of resistive exercises as a means of conditioning individuals for participation in physical activity. Progressive resistive techniques, as practiced today, are certainly not new, for the Greeks, as early as 700 B. C., recognized the importance of heavy resistive exercise methods for building strength. For hundreds of years man has observed that use of muscles in heavy work results in increases in size and strength. However, the nature and limitations of these increases were not understood, and only through the enterprising efforts of researchers of the past 65 years has knowledge been obtained regarding the physiological laws that determine development of strength and hypertrophy and the kinds of exercise that will produce these changes in muscle. Careful research initiated by Morpurgo, Petow and Siebert (58), and Muller (45) has produced scientific evidence that has contributed immeasurably to present knowledge and understanding of the nature of muscle hypertrophy and strength development.

In 1897 Professor B. Morpurgo (58:147) of the Pathological Institute of Siena conducted a classic study of the effect of exercise upon muscle. Using the sartorius muscles of dogs, Morpurgo found that increase in size of the exercised muscle was attained without an increase in the number of muscle fibers. From a comparison of average cross section area of fibers from the muscle removed before exercise with that of the fibers from the muscle taken out after exercise, Morpurgo concluded that the increase in cross section of the exercised muscle was due to an increase in the cross section of individual fibers. The results of this investigation indicated that exercise causes the muscle to become larger. On the basis of his observation of the size of muscles in athletes, Roux (59:58) theorized in 1905 that it is not just exercise, but the kind of exercise that made the difference. Very few people understood Roux's explanation of the principles involved in his theory until his young assistant, Lange (59:58), translated the ideas into what is now recognized as a basic physiological law that governs the development of muscles. The Roux-Lange theory of overload was proved by Petow and Siebert (58:148), who in 1926 provided the first real evidence that muscle hypertrophy results from an increase in the intensity of work done, total amount of work being of little significance. They also showed that the greater the intensity of the work, the greater the amount of muscle hypertrophy. Muller (44, 45) conducted a series of studies in Germany extending over a period of ten years in an attempt to determine the most effective way to produce the necessary training effect in muscle for the development of strength and hypertrophy. The findings of Muller's research were that a 40 to 50 per cent of maximal contraction held for 6 seconds or a maximal contraction held only momentarily just once a day will cause the muscle to develop strength as rapidly as is possible (45).

Throughout the years much has been learned, both from practical experience and research, about the development of strength and hypertrophy of muscles and the importance of strength in performing physical activities. Although it is well established that the strength of muscles can be increased by progressive resistive exercise, there is little agreement as to the most effective method by which this can be achieved. Because of this, there is no universally accepted method of muscle training. Many procedures have been described and applied, and each has been based on one or more of the different methods of application of the overload principle. Overloading to develop strength in muscle may be accomplished in several ways. Siebert (59:41-42) found that increase in the size of a muscle was a function of speed of running rather than its duration. Muller (45:47) reported that 6 seconds of isometric contraction at 40 per cent of maximal intensity once per day is enough to increase strength. Research on dynamic resistive exercise by DeLorme (23:645) has shown that the weight load must constantly be kept at overload to ensure progressive increase in muscle strength.

Numerous studies during the past twenty years have examined the effectiveness of different types of exercise regimes on the improvement of muscular strength, endurance, speed, power, coordination, and flexibility. Much attention has been given to the relative effectiveness of isometric and isotonic forms of exercise and to the merits of different systems of resistive exercises. The research reviewed in connection with this study will be presented as it is related to the application of different methods of overload in the development of the strength, endurance, speed, and explosive power of the muscle.

Strength

Strength as defined by Steinhaus (59:85) is the pulling force or tension that a muscle exerts as it contracts or shortens. For the purpose of developing strength, an individual may employ weights, springs, static contraction, or body weight as resistance. The recent trend in strength development programs has been toward the use of static contraction or heavy isotonic work.

Isometric Contraction. In 1953 Hettinger and Muller (31:111-126) used isometric contractions in various exercise routines. It was their purpose to determine just how much increase in intensity of work is necessary to make a muscle grow in strength. The findings from their extended investigation led to the conclusion that a single daily isometric contraction held for about 6 seconds at approximately 50 per cent of maximum made the muscle grow in strength as rapidly as possible. Crakes (19) conducted a later study in which he employed a 6-second daily contraction against resistance equal to two-thirds strength. This program resulted in a 23 per cent gain in strength during the first week of training. Liberson and Asa (36) in a recent report stated that repeated 6-second isometric contractions produced a more rapid increase in strength than a single 6-second isometric contraction. Rarick and Larsen (52) investigated the effect of differences in the frequency and intensity of daily 6-second static contractions on muscular strength. The results of their study in general supported the findings of Hettinger and Muller (31). In a similar study at The Pennsylvania State University, Taylor (35:144-145) compared the effectiveness of four training methods using static contraction for increasing muscular strength. The training methods used were: maximum pull held for 6 seconds, maximum pull held for 12 seconds, two-thirds maximum pull held for 6 seconds, and two-thirds maximum pull held for 12 seconds. Taylor concluded that no one of the four static contraction methods was significantly superior to any of the others for the purpose of increasing strength of the muscles involved in the movement employed in the study. Other studies using isometric contraction routines reported by Asa (1), Darcus and Salter (20), Hellebrandt (29), and Wolbers and Sills (66) found significant strength gains.

A study to determine the effect of static training upon isometric strength of the elbow flexors and the knee extensors was made by Petersen (46) in 1960. The results of this study indicated that one daily maximum isometric contraction had no effect on the isometric strength of the muscles, and that ten daily maximum isometric contractions had a tendency to increase the isometric strength of the exercised muscles. In a similar study in New Zealand, Wallace (61) found no significant gain in elbow flexion strength as a result of either brief static or dynamic contractions after four weeks of training.

Isotonic Contraction. Most of the early studies pertaining to resistive exercise techniques and methods dealt with muscle training of a dynamic nature over a full range of joint movement in which the basic principles of the training programs were largely based on the experiences of professional weight lifters. In the past decade, studies by DeLorme (23), Hellebrandt and Houtz (28), and Rasch and Morehouse (48) in the field of physical medicine and rehabilitation; Capen (10, 11), Counsilman (18) and Darcus and Salter (20) in the field of physical education and physiology; and, Chui (12), Garth (27), and Wickstrom (63), in the field of athletics, have helped to establish weight training as a valuable adjunct to conditioning programs. In 1945 DeLorme (23) devised a system of heavy resistive exercises that has since been widely applied in athletics, physical education, and physical medicine. DeLorme established the following training principles: (1) increases in the strength of muscles can be accomplished by lifting a heavy weight a few times, (2) improvement in performance of the circulatory system can be accomplished by performing many repetitions of a movement with a light resistance, and (3) these two methods are not interchangeable. The DeLorme concept of muscle training is corroborated by Counsilman (18), who points out that no single type of exercise will produce improvement in both strength and endurance but that heavy resistive exercise will cause an increase in strength.

A study to determine the effects of systematic weight training on strength, power, and endurance was conducted by Capen (11) in 1950. The results of this investigation indicated that significantly greater gains were made in strength by the group trained with weights than by the control group that participated in other activities. In a second study of different programs of heavy resistive weight training exercises, Capen (10) found that the programs employing heavy resistance for a few repetitions to be superior in developing strength. Results obtained from other studies substantiate the findings of DeLorme (23), Capen (10), and Counsilman (18). In an investigation by Hellebrandt and Houtz (28), subjects gained up to 161 per cent in strength working for 5 minutes daily for a period of ten days against a heavy load. When the load was reduced by 75 per cent and the number of repetitions greatly increased, no gain in strength was achieved In a more recent investigation conducted by Berger (6), weight training groups performing with a resistance that permitted less than three or more than nine repetitions had smaller gains in strength than did groups performing exercises with a resistance that allowed between three and nine repetitions for one set.

Isometric vs. Isotonic. Heavy resistive exercises involving isotonic muscular contractions have been widely accepted as beneficial and effective for developing strength. However, the research of Muller (45), which revealed the possibilities for different methods of strength development through the use of isometric contraction, has initiated much discussion as to the relative merits and effectiveness of static and dynamic training methods. Recent investigations have been conducted in an attempt to determine which of the two methods of training, isometric or isotonic, is most effective for strength development.

As early as 1928 Siebert (58) performed an experiment in which he stimulated the gastrocnemii of frogs. One leg of each frog was tied firmly to the frog board to prevent movement, and the other leg was allowed to move freely. Both legs were stimulated with identical strengths of tetanizing currents an equal number of times on fourteen successive days. When the muscles were examined after exercise, those submitted to isometric contraction were on the average 13 per cent heavier than those that were allowed to contract isotonically.

The purpose of a study by Rasch and Morehouse (48) was to determine the effects of static and dynamic exercise on muscular strength and hypertrophy. They reported that male subjects who performed isotonic exercises showed greater gains in strength and hypertrophy than did subjects who exercised isometrically. They also observed that very little of the strength gains from either isotonic or isometric exercises was transferred to unfamiliar situations.

The relative effectiveness of isometric and isotonic contraction methods on the development of strength and muscle girth was studied by Lorback (35) at The Pennsylvania State University in 1958. One method employed short periods of static contraction, and the other used regular weight training methods that required the subject to lift a weight for a maximum of ten repetitions. Both groups made significant gains in strength and muscle girth, but no significant difference was observed between the two methods.

Rasch (49) has reported that, as a result of findings from carefully conducted research, it is now generally agreed that the training stimulus to increase muscular strength is the development of tension. Furthermore, there appears to be no great difference between the amount of tension that can be recorded in a single maximum isometric contraction of flexor muscles of the forearm and the amount of weight that can be lifted in a single maximum isotonic elbow flexion. Steinhaus (59:136) reports that Hettinger and Muller have concluded that oxygen deficit is not the stimulus for muscle growth as originally reported, but the stimulus appears in some way to be related to tension.

An investigation by Wilkie (64) revealed that in static effort maximum tension can be maintained and that as the speed of muscle contraction increases the amount of tension produced during the contraction decreases. The amount of tension produced in muscle contraction is thus dependent on whether or not the muscle is allowed to shorten and on the size of the load. If the muscle is fastened at both ends, its contraction will be isometric and the outcome will be tension. According to Asmussen (3) if the muscle is not fastened at both ends, it will shorten on stimulation, and if not loaded, will attain its new length of equilibrium without producing any tension. In another report it has been stated by Asmussen (2) that when a muscle under tension is forcibly lengthened each active muscle fiber is being stretched. This stretching results in the production of higher tension in the fibers than when the muscle is shortening as when lifting a load.

The effects of various exercise programs on isometric tension were explored by Baer and his co-workers (4), who designed an investigation in which 63 subjects were divided into six exercise groups. The subjects in each group trained with a different isotonic or isometric routine. The results of this study were that maximal increase in isometric tension was produced as a result of isometric exercises at a slow rate of ten per minute. Heavy resistive isotonic exercises at the same rate of ten per minute produced an increase in isometric tension that was almost as great.

In a study of the effects of isometric and isotonic exercises on elbow flexor muscle groups, Mathews and Kruse (42) divided 120 male college students into two exercise groups. One group exercised isotonically on the Kelso-Hellebrandt ergometer with a weight load for each subject equal to 3/16 of his maximum strength. The other group exercised isometrically by exerting maximum effort on three consecutive 6-second pulls on a strap. Each large group was subdivided into four smaller groups of fifteen subjects each. The subgroups exercised respectively two, three, four, or five times weekly over a four-week period. The results of this study were that as the exercise frequency increased, more subjects from both isotonic and isometric groups made significant gains in strength; however, the subjects who exercised isometrically made greater strength gains than did those who exercised isotonically. In a similar study by Liberson and Asa (36), the effectiveness of daily 6-second isometric exercises as compared with the DeLorme (23) isotonic exercises was investigated in 26 normal individuals. The findings from this investigation were that brief isometric exercises resulted in more rapid strength gains than did the program of isotonic exercises.

Nancy Salter (56) conducted an experiment on normal individuals to compare the effect of training by repeated sessions of isometric contraction, made at repetition rates of either two or fifteen per minute, with the effect of comparable sessions of isotonic contraction exercises. After sixteen training sessions extending over a period of four weeks it was found that all training procedures resulted in an improvement in muscle strength, but no significant difference was found between the four different methods used.

In a comparison of static with concentric exercise methods in which one group of subjects performed weight training exercises in the usual manner and the other group of subjects held a weight in a prescribed position for 6 seconds, Rogers (53) found no significant difference in strength gains made by the two groups.

With regard to the use of isometric and isotonic exercises for conditioning athletes, Ferguson (26) has stated that progressive resistive exercises are of value in developing and maintaining muscular strength and power, but in athletics these exercises must be carried over the full range of joint motion. Otherwise, exercise may result in the development of short powerful muscles that limit athletic function.

Endurance

Endurance may be defined as the ability of the body to withstand the stress of prolonged activity. Steinhaus (59:60) has stated that in general all endurance depends upon circulation but that muscle endurance is also related to strength. Thus, muscle endurance is the ability to go on lifting the same weight many times or the ability to sustain a muscular force. Muller (45:47) contends that a strong muscle does not always mean better performance in practice and that ways other than static contraction must be employed for the adaptation of ventilation and circulation to increased muscular strength. With the introduction of isometric contraction into the training program, many coaches and athletes have decried the use of this method of developing strength because it is felt that static exercise does little for the development of endurance. In other types of exercises involving dynamic activity, such as weight training, both muscle strength and endurance are developed in proportion to the nature of the lifting regimen and the intensity of the work.

Isometric Contraction. Steinhaus (59:88-92) and Asmussen (2, 3), contend that in isometric contraction the active muscle swells, becomes hard, and forces the contained blood into the veins. The blood flow to the muscle will be partly or totally blocked. During an isotonic or dynamic contraction, the blood flow through the muscles will also be partly or totally blocked. Maximal dynamic work at a high intensity comes close to resembling static work. In a study of the energy cost of isometric exercise, Clarke (13:6) found a linear relationship between intensity of contraction, amount of oxygen uptake, oxygen debt, and total oxygen requirement. This means that during isometric contractions of near maximal tension the muscle depends to a great extent on the energy stored in the muscle fibers themselves, and the greater the tension developed and the longer the time of contraction, the more the muscle will be dependent upon anaerobic processes for the necessary energy to maintain the contraction. From results of studies reported by Steinhaus (59:88-92), Asmussen (2, 3), and Clarke (13) it appears that the development of muscular endurance from isometric contraction exercises may be restriced as a result of constriction of the blood flow and oxygen supply to the muscles. However, from the results of a study reported in 1949, Asmussen (3) found a greater increase in muscle endurance as a result of training by sustained isometric contractions than by intermittent isometric contractions. Liberson and Asa (36) measured endurance in trained muscles by a sustained pull on an isometric myograph cord until exhaustion. The time from the beginning of the pull until the moment when the myograph showed 50 per cent of the initial amplitude was taken as the index of endurance. Test results indicated that training with brief repeated isometric contractions produced greater increases in muscle endurance than did training with a single isometric contraction. Steinhaus (59:86) has stated that the ability of a muscle to make many repetitions of a movement or exercise is related to strength irrespective of how the strength be developed.

Isotonic Contraction. Massey *et al*. (40:58) have reported that increased muscular endurance results from increased strength and hypertrophy, especially if high repetition and low resistance is emphasized in training. According to DeLorme (23) it is a mistake to attempt to improve endurance through high resistance and low repetition methods. He contends that improvements in endurance result from programs that employ greater numbers of submaximal contractions. It is possible to build both muscular strength and endurance with proper balance between high resistance-low repetition and high repetition-low resistance movements.

Capen (11) found that a group of 42 subjects of a weight training class improved as much in both muscular and circulo-respiratory endurance as did a group of 29 subjects of a conditioning class. The investigation extended over a period of eleven weeks in which both groups met for a 40-minute session twice a week. The weight training class performed dumbbell and bar bell exercises, and the conditioning class performed strenuous activities that emphasized the endurance element.

In a recent article Ferguson (26) stated that muscle endurance is most effectively produced by repetitious motions with a submaximal load. The use of heavy resistance results in muscular fatigue so quickly that the muscle fails to improve its ability to perform a given movement in repetitious fashion. Similarly, too little resistance fails to provide the necessary training stimulus for strength development that is necessary for repeated performance of the given act.

Mathews and his associates (41) designed an experiment in which they studied the effects of exercising the muscles of one arm upon endurance of that arm and upon endurance of the muscles of the opposite arm. Twenty-eight Springfield College students exercised the elbow flexor muscles of one arm three times a week for four weeks on the Kelso-Hellebrandt ergometer. During each training session, the subject exercised until the weight load could no longer be lifted. The improvements in endurance for the exercised arm were statistically significant, but no significant increase in endurance was observed in the unexercised arm. In another investigation of the same nature Kruse and Mathews (34) divided subjects consisting of 60 male college students into four experimental groups. All subjects were periodically subjected to ergometric exercises of the left elbow flexors for a four-week period. During each week fifteen subjects exercised twice, fifteen exercised three times, fifteen exercised four times, and a group of fifteen exercised five times. A control group of equal size that performed no exercise was matched with each experimental group. In the groups that exercised three, four, and five times weekly, statistically significant increases in endurance of the exercised elbow flexors were observed. No statistically significant gains in strength or endurance were observed in the unexercised elbow flexors of any of the experimental groups, and no significant improvements in strength or endurance were found in the flexor muscles of either elbow of the control groups.

Isometric vs Isotonic. Many studies have compared the relative effectiveness of isometric contraction and isotonic exercises in the development of muscular endurance. Comparing isometric contractions with dynamic exercises of equal intensity, Clarke (13) found the oxygen uptake to be significantly smaller and the oxygen debt significantly greater during isometric contractions than during dynamic exercises. Thus, it would appear that exercises of an isotonic nature favor the development of muscular endurance. Baer and associates (4) studied the effects of various exercise methods on work capacity in 63 subjects who performed isometric and isotonic exercises involving the wrist flexors and two complex exercises involving the entire upper extremity. The subjects were divided into six experimental groups for the purpose of training by the following exercise routines: (1) high resistive isotonic exercise, ten contractions per minute over a four-week training period, (2) high resistive isotonic exercise, thirty contractions per minute over a four-week period, (3) high resistive isotonic exercise, ten contractions per minute over a four-week training period with a load greater than that used in training routine '1', (4) low resistive complex motion of upper extremity, ten contractions per minute during a six-week training period, (5) high resistive isometric exercise, ten contractions per minute over a six-week period, and (6) high resistive isotonic exercise, ten contractions per minute with a lesser weight load than in '1'. Each experimental group exercised the upper right extremity by the prescribed routine one period a day five times a week. Marked increases in work capacity, as determined with an ergograph, ranging from 115 to 133 per cent were produced by both isometric and isotonic exercises.

Dennison _et_ _al_. (24) at the University of British Columbia, conducted an investigation in which college men were placed in experimental groups of ten subjects each. One group followed a regular weight training program and the other performed isometric exercises. The subjects were tested before and after training twice a week for eight weeks on chinning and dipping performance. Both groups made significant gains on each measure, but the difference in improvement as a result of the two training methods was not statistically significant. Similar results were obtained by Howell, Kimoto, and Morford (32), who compared endurance gains resulting from isotonic exercises with those produced by isometric exercises. Muscle endurance was determined by an all out performance for two minutes on a bicycle ergometer with a resistance of 14 kilograms. The subjects in one experimental group performed regular isotonic exercises; the other experimental group performed isometric contraction exercises. A control group of equal size participated in normal physical education activities. After eight weeks of training both experimental groups showed improvements in endurance significant at the .01 level. The difference between mean improvements of the two experimental groups was not statistically significant.

Lawther (35) reported a study conducted by Swegan at The Pennsylvania State University in which a comparison was made of the effects of isotonic and isometric training programs on certain speed movements and muscular endurance. Tests for endurance consisted of movements involving right elbow flexion and extension, left elbow flexion and extension, right knee flexion and extension, and left knee flexion and extension. Included also was a bicycle ergometer test of endurance. Swegan found that muscular endurance based on composite scores increased significantly as a result of both isometric training and isotonic training. No significant difference was observed between improvements made by the different methods, other than in knee extension movement where it appeared that static contractions were superior to deep knee bends in developing endurance in the muscles involved.

Petersen (46) obtained measures of the isometric strength and endurance among a group of trained subjects who participated in one of the following exercise routines: (1) one daily maximum isometric contraction, (2) ten daily maximum isometric contractions, (3) ten daily eccentric muscular contractions, or (4) fifteen minutes of heavy dynamic work on a bicycle ergometer. No improvement in muscular endurance in sustained isometric contraction resulted from any of the training programs as conducted in this study. Wallace (61) performed a similar experiment on a group of college women and reported an increase in endurance as a result of isotonic training significant at the .01 level. The isometrically trained group also showed increased endurance that was statistically significant at the .05 level.

Speed

Speed is the ability to move the body or parts of the body rapidly through space. Massey *et al*. (40:58) states that hereditary characteristics of the nervous system, the physiological condition of the muscle, and motor learning are the factors that determine speed of muscular movement. Steinhaus (59:22) has pointed out that speed of movement can be improved by increasing the strength of the muscles, but speed is more than strength. It is dependent upon the ability to put together sensory impressions and voluntary motor acts. Thus, it appears that speed may be increased by improvement of the physiological condition of the muscle and through practice of the movements involved in a specific skill in order to coordinate the muscle action.

Isotonic Contraction. Numerous investigations have been conducted in an attempt to determine the effect of heavy resistive exercise on speed, agility and coordination. Chui (12) was among the first to investigate the effects of systematic weight training on the speed of movement. In his study, subjects in the experimental group performed weight training exercises, and the control group participated in a regular physical education program that did not include weight lifting. All subjects were tested at the beginning and at the end of the training program on speed in running the 60-yard dash. The results showed that both groups made improvement in running speed with a mean gain of 0.33 seconds for those trained with weights as compared to a 0.16 seconds for the nonlifters. From findings in this study, Chui concluded that the probability of improving speed as a result of systematic weight training does exist.

1951 Zorbas and Karpovich (67) conducted a study to determine the effects of weight training upon the speed of muscular contraction. In this investigation the experimental group consisted of three hundred weight lifters and the control group contained three hundred nonlifters. The final results indicated that in speed of rotary arm movement the weight lifters were significantly faster than the nonlifters. Using the same method for measuring arm speed, Wilkin (65) found that systematic weight training over a period of one semester did not slow the speed of rotary arm movement for a group of thirty beginning lifters. He also found that speed of rotary arm movement for a group of fifteen experienced weight lifters was as great as that of a control group made up of golfers and swimmers. Furthermore, the weight lifters improved in speed as much or more than the control group during one semester of training.

Speed of movement and muscular coordination as related to strength gained through weight training were explored by Masley and co-authors (38) in 1953. The results of this investigation revealed that a weight training group made a significantly greater gain in strength than two control groups and that improvement in speed of rotary arm movement and muscular coordination appeared to be related to strength increases. From the findings of his study at the University of Tennessee, Capen (11) reported that subjects who participated in weight training exercises improved more in the events involving speed than did the subjects who participated in strenuous conditioning activities.

DeLorme and associates (21) investigated the effects of progressive resistive exercise as applied in clinical practice upon muscle contraction time. One group of subjects participated in progressive resistive exercises over a period of four months. Another group served as controls and did no exercise. In order to determine whether actual changes in muscle strength had been produced by exercise, all subjects were tested for 1 R. M. (one maximum repetition) on elbow flexion and knee extension. Circumference measurements of the biceps and thigh were taken before and after training to ascertain the amount of hypertrophy. The findings from this study showed increases in biceps and thigh circumferences and considerable improvement in knee extension and elbow flexion strength. The results of the post exercise contraction time test gave no indication that progressive resistive exercise produced a slowing of contraction time in the muscles involved in knee extension and elbow flexion. In summarizing this investigation, DeLorme pointed to the possibility of other individuals reacting differently to similar exercise regimes or to progressive resistive exercises given in a different manner over a longer period of time.

Lawther (35:142-144) reported four studies completed at The Pennsylvania State University in which the effect of weight training on speed was investigated. Hairabedian (35:142) compared strength and speed changes made by a weight training group with those made by a group that played volleyball and a control group that participated in no training activity. All subjects were tested for arm strength and speed of rotary arm movement before and after a six-week period in which the experimental group performed progressive resistive exercises with weights. The test results indicated no significant gain in strength or speed for the control group. The group that participated in volleyball made a slight increase in strength and had a marked loss in speed. Significant gains in both strength and speed were made by the weight trained group. Two years later in a study conducted by Tominaga (35:142-143), an attempt was made to determine the effect of weight training upon speed and accuracy in the pitching of a baseball. After a six-weeks training period, neither significant improvement nor loss resulted from progressive resistive exercises with weights. In 1957 Meisel (35:143) studied the effect of strength gained through weight training upon maximum speed in running a distance of 10 yards. Subjects in the experimental group performed exercises with bar bells and weighted shoes on Monday, Wednesday, and Friday each week for a period of six weeks. Findings from the study are that statistically significant increases in strength had resulted from weight training but that there was a loss in speed of running significant at the .02 level.

In a study designed to determine the effect of weight training on movement time for arm flexion and extension and for leg flexion and extension, Yankosky (35:144) found only slight increases in movement time as a result of eleven weeks of training with special exercises for developing the muscles involved in the speed movements measured.

Isometric vs. Isotonic. In another study at The Pennsylvania State University conducted by Swegan (35:146-147), it was found that movement speed was slowed significantly by each experimental method employed in the training program. One training method consisted of 6-second static contractions of two-thirds maximum effort, and the other method utilized progressive weight training exercises. As a result of this study, Swegan concluded that training programs designed for speed development should include low resistive exercises.

Mention has already been made of an investigation conducted by Baer and associates (4) in which they attempted to determine the effects of various exercise programs on isometric tension, endurance, and reaction time. The data on reaction time revealed increases following heavy resistive isotonic exercises; however, on the basis of available evidence, it was not possible to conclude that these changes could be attributed to specific exercises. No statistically significant changes in reaction time resulted from either isometric exercises or complex movement exercises.

In a report on conditioning exercises for athletes, Ferguson (26) asserted that static contraction exercises, or those exercises which allow for only a limited range of movement, produce muscles that are of little value to athletes. Such muscles can support an inordinate amount of weight, but often lack the agility and speed necessary to move the weight into position for the required mechanical advantage.

Power

Massey et al. (40:58) define power as the rate of doing work; thus, muscular power is related to the load that a muscle or muscle group can move over a specified distance in a given period of time. Resistive exercises contribute to the development of power through improved muscle strength.

Isotonic Contraction. Many investigators interested in human performance have experimented with both isometric and isotonic contraction methods in an attempt to determine the effects of strength gained through resistive training on performance in activities involving power movements. In 1950 a number of weight trained subjects were tested by Chui (12) for the purpose of determining the effect of systematic resistive exercises upon athletic power. Among the tests used to measure power were the Sargent jump running, the Sargent jump standing, and the 12-pound shot put from a stand. Findings from this study are that the weight trainees improved in all power events. Capen (11) employed similar tests for determining the relationship between strength gained through weight training and improved performance in power events. He found that a group of subjects trained with weights made a significantly greater improvement than did a control group of nonweight trained subjects.

Counsilman (18) found that eighteen weight lifters at Courtland State Teachers College in New York were above average in standing broad jump and jump and reach measurements.

Garth (27) combined systematic weight training exercises with pre-season basketball practice in his study at the University of Iowa in which nineteen varsity athletes served as subjects. In this program weight training exercises designed for developing strength and power in arms, shoulders, and legs were performed three times a week for six weeks. Garth employed the jump and reach test as a measure of power and found an average gain in jumping height of almost 3 inches with a range of improvement from 1.75 to 6.5 inches.

A study conducted by Eckstrom (25) at the University of Iowa investigated the effect of weight training upon the velocity of a thrown baseball. An analysis of the data indicated that weight training does increase the possibility for throwing a baseball with greater velocity as a result of increased strength.

A significant increase in leg power of an experimental group resulted from a program at The University of Texas (9) in which the subjects wore weighted vests, hand weights, and ankle weights while performing in a system of speed exercises developed by McCraw (37). This investigation extended over a period of six weeks during the spring of 1962. The exercise program consisted of seven exercises designed to improve strength, speed, and power in the muscle groups involved. During the first two weeks of the program each inning, or work bout, extended over a period of 10 seconds, followed by a 10-second rest period between innings. In the second two weeks of the training program the time of work for each inning or bout was extended to 15 seconds. Each 15-second inning was followed by a 10-second rest interval.

The third two weeks of the training program consisted of 20-second work innings or bouts followed by 10-second rest intervals. The experimental group, consisting of fifty athletes, performed all exercises wearing weighted vests, hand weights, and ankle weights, through ten innings or bouts of work during each work-out period.

Isometric vs. Isotonic. Asmussen (3) found a greater effect on muscle endurance in static contractions after training by sustained isometric work than by intermittent isometric exercises. No significant effect on muscle power was observed. Findings from this study led Asmussen to suggest that it may be possible to train muscles in ability to perform anaerobic work without effecting a change in muscle power.

Berger (5) reported a study in 1962 in which he compared the effect produced by static and dynamic training upon a movement involving muscle power. Findings from this study were that subjects who trained dynamically made greater gains in ability to perform a movement against a near maximum resistance than did a statically trained group. Conversely, subjects who trained statically improved more in performance on a static strength test than did a dynamically trained group.

In a study of the effects of isotonic contraction training on speed, force, and strength, Meadow (43) found that both isometric and isotonic training produced statistically significant improvement in performance on chinning and dipping measurements. No significant difference was observed between the isometric group and the isotonic group in performance on the dipping measurement, but the isotonic groups made a significantly greater improvement in chinning performance than did the isometric group.

Summary

This review of the literature on isometric and isotonic contraction in muscle training reveals that both methods of training cause a significant increase in muscle strength, and, though research has produced conflicting results, there appears to be no real difference between the two methods of training in production of available strength relative to the performance of specific activities.

The effect of isotonic training seems to favor the improvement of muscular endurance, and training by sustained isometric contraction appears to produce greater endurance on static contraction measures than does training by numerous intermittent isometric contractions.

Early research on the effect of weight training on the speed of muscular contraction has demonstrated that programs of progressive resistive exercises do not result in a loss in speed of muscular contraction, but that increases in speed appear to be related to strength gains produced by weight training. However, recent investigations have produced evidence which indicates the possibility of a loss in movement time resulting from programs consisting of only heavy resistive exercises.

Numerous studies have shown that improved performance in activities involving muscular power occurs as a result of progressive resistive exercise training, and that both isometric and isotonic training methods are effective in developing specific muscle groups upon which performance of a special movement or activity is dependent.

II. PROCEDURE

The study was conducted during the Spring Semester, 1962-63. The subjects were all volunteers and were obtained by contacting individuals in required physical education classes during the month of December, 1962. The purpose of the study was explained and the procedures to be followed were outlined. Those persons who agreed to particcipate were scheduled during the regular registration period for a special class to meet from 4:00 to 5:00 p.m. on Monday, Wednesday, and Friday each week.

The first two weeks of the semester from February 4 to 15 were used to obtain initial measurements and to assign subjects to their respective exercise programs. After spending one class session in learning the techniques of the exercises, the subjects began strength training on February 20 and continued three times per week for nine weeks. Measurement of final status was completed during the two-week period from April 29 to May 10.

The subjects spent approximately 30 minutes during each class period in executing the movements of their respective programs. They engaged in no other physical activity during the period other than these movements. Furthermore, they were encouraged to refrain from participating in physical activity outside the class period.

Testing Procedures

In selecting the tests for the study, it was necessary to determine first the muscle groups on which to measure the attributes of strength, speed, endurance, and power. Three criteria were considered in reaching this decision. First, the muscles should be sufficiently strong and the movement extensive enough to obtain an adequate response in the four attributes under consideration. Second, the neuromuscular patterns should be reasonably simple to preclude complicated coordinations in the execution of the movement. Third, it should be possible to involve the muscles equally well in the exercises of the three resistive programs. On the basis of these criteria, the decision was made to use the muscles and movements of the preferred arm and leg as follows: (1) extensor muscles of the forearm and flexor muscles of the upper arm involved in thrusting the hand straight forward from a position in front of the shoulder; (2) extensor muscles of the lower leg and extensor muscles of the thigh involved in straightening the leg from a flexed position.

The tests used to measure the four attributes of strength, speed, endurance, and power in each of the limbs are described hereinafter.

Strength Tests

The strength of the muscles was measured with an aircraft cable tensiometer (Figure 1, Page 38). The testing procedures were adapted from those developed by Clarke (15:2) for use with this instrument. Clarke's directions are for testing strength at a single joint while the measurements in this study involved all joints in the limb. Two persons were required to obtain the strength of the subject in each of the tests. One person guided the subject to ensure correct performance and the other manipulated the tensiometer. After one practice, the subject took two official trials with 30 seconds rest between them. Both trials were recorded and the better of the two was used as the score.

Using the best effort in N trials is the normal procedure in tests of this nature and is considered to be reliable. Retest coefficients of .92 and above were obtained by this procedure for the tests in this study. The instrument itself has been calibrated, and under carefully controlled conditions, the testing technique is dependable. The differences in scores from trial to trial therefore are likely to be due to variations in contraction of the muscles. It is hardly possible for an individual to exert more than his maximum strength on any one trial. On the other hand, it is entirely probable that one will perform below his capability on one or more of several trials.

Strength of Arm (Figure 3, Page 39). The subject sat with his back against a post and the shoulder of the preferred arm level with and anterior to the attachment for the tensiometer cable. The hand of the preferred arm was raised to a point anterior to and on level with the shoulder and placed in a strap attached to the tensiometer cable. With the palm forward and the fingers pointing upward, the strap was positioned at the base of the hand, thus allowing the force to be distributed directly to the forearm. The tensiometer cable was adjusted so that the forearm formed a 90-degree angle with the upper arm as the subject pushed forward against the strap.

Strength of Leg (Figures 2 and 4, Pages 38 and 39). The subject assumed a supine position on the strength testing table with his shoulders against braces. These braces consisted of two boards padded with foam rubber and anchored against the posts to which the tensiometer cable was attached. Attachments for the cable were 6 inches above the shoulder and were located on both sides of the table to permit measurement of the preferred leg. A strap fastened to the cable was placed over the instep of the foot and was positioned so that the force was distributed directly to the leg. The cable was adjusted to form an angle of 110 degrees between the leg and thigh as the subject pushed forward against the strap.

Speed Tests

An electric chronoscope (Figure 5, Page 40) yielding times to one hundredth of a second was used to measure the speed of the muscles. The chronoscope was activated simultaneously with a buzzer, which served as the stimulus for the movement. A leaf type microswitch was used to stop the chronoscope. A plug attached to one end of a nylon cord, 1/8 inch in diameter, was pulled from the switch as the movement was completed. The opposite end of the cord was fastened to the limb being measured, and the distance to be timed was controlled by the length of the cord.

After assuming the position for the test, the subject was given a verbal ready signal. This signal was followed by the buzzer stimulus within 2 to 6 seconds. This time interval between signal and buzzer was varied by random selection. On each of the speed tests for the arm and leg the subject was allowed two practice trials after which he had ten trials that were recorded. Of these ten trials, the highest and lowest were discarded and the average of the remaining eight was used as the score. The same procedure was followed for starting speed except that four trials were given and the average of the middle two was used for the score. The split-half coefficients corrected by the Spearman-Brown formula were.90 for eight trials on the arm speed tests and .94 for the leg speed test. The coefficient for starting speed was .88. Eliminating extreme scores has been advocated in timing events since subjects are as likely to anticipate the stimulus and obtain spuriously high scores as to fail to respond and obtain scores below their capacity.

Speed of Arm (Figure 6, Page 40). The subject sat in a chair with the back of the shoulder of the preferred arm toward and on level with the microswitch. The preferred arm was raised and flexed to the maximum at the elbow so that the hand was held palm forward level with and anterior to the shoulder. The nylon cord leading to the microswitch was fastened to the hand and was adjusted so that the plug on the other end was pulled from the switch after a movement of one foot. The subject moved the hand straight forward on hearing the buzzer.

Speed of Leg (Figure 7, Page 41). The subject lay on his back on a table with his head toward the microswitch. The preferred leg was raised and flexed to the maximum at the hip with the foot resting on a bench 12 inches high above the table. The lower leg was thus in a horizontal position with the foot level with the microswitch. The nylon cord leading to the microswitch was fastened to the foot and adjusted so that the plug on the other end was pulled from the switch after a movement of one foot. The foot was moved forward upon sounding of the buzzer.

Starting Speed (Figure 8, Page 41). The subject assumed a semicrouch position for the standing start with the back foot against a starting block. The microswitch was level with the waist about three feet behind the subject. The nylon cord from the microswitch was fastened to the waist band of the shorts and was adjusted so that the plug on the other end was pulled from the switch after the subject moved 6 yards. Upon hearing the buzzer, the subject started as rapidly as possible as in running a dash.

Endurance Tests

Muscle endurance was measured by an ergometer, wherein the subject contracted the muscles against a resistance until he could no longer maintain a specified cadence. Since the ergometers available commercially are designed for small muscles or for movement at a single joint, it was necessary to construct a special apparatus to measure endurance of muscles involved in the total movement of the arm and leg. The apparatus consisted of a table, 7 feet long, 30 inches wide, and 30 inches high, upon which the subject sat or lay as he took the tests. Levers were mounted on either side of the table at one end and were connected with a one-inch rod 18 inches above the table. Cables joined each of the levers to weights mounted underneath the table at the opposite end. The subject pushed against the bar joining the two levers, thus lifting the weights. A counter registered the number of times the weights were lifted before the onset of fatigue.

Each subject was allowed sufficient practice on the apparatus until he could maintain the proper cadence. He then was given two trials, one on each of two days. The better of the two trials was used as the score. Retest reliability coefficients by this procedure were .97 for the arm test and .95 for the leg test.

Endurance of Arm (Figures 9 and 10, Page 42). The subject sat on the table so that he could grasp the bar midway between the two levers. The arm was flexed to the maximum at the elbow thus placing the bar level with and in front of the shoulder. The subject pushed the bar forward to full arm extension and returned it to the starting position for one complete movement. The exercise was repeated in cadence to a metronome at the rate of 36 movements per minute. The weight for each subject was 50 per cent of his arm strength. The subject stopped when he could no longer maintain the prescribed cadence.

Endurance of Leg (Figure 11, Page 43). The subject assumed a supine position on the table with his feet toward the bar. The foot of the preferred leg was placed in a stirrup, which was fastened to the bar midway between the two levers. The body was adjusted so that the thigh was vertical forming a right angle with the trunk and with the foreleg, which was then parallel with the trunk and table. The subject pushed the bar forward to full leg extension and returned it to the starting position for one complete movement. The exercise was repeated as many times as possible to the cadence of a metronome at the rate of 26 movements per minute using a weight of 25 per cent of the leg strength.

Power Tests

Power was assessed by determining the effectiveness of the muscles in contracting rapidly against resistance. The body itself provided the resistance for the leg muscles in the jump and reach test. The measurement of power of the arm muscles was the distance the subject could project a softball in a rapid extension of the arm with the body immobilized.

Power of Leg (Figures 12, 13, and 14, Pages 43 and 44). The jump and reach is universally accepted as a measure of leg power, and the chalk board method is commonly used in scoring this test. A chalk board marked off with lines one-half inch apart was used in this study. The chalk board was mounted in a sliding frame on a wall so that it could be adjusted to the subject's reaching height.

The subject stood underneath the chalk board with the side of the preferred arm next to the wall. With the board raised to maximum height, the preferred arm was extended upward as high as possible with fingers together and palm toward the wall. The board was lowered until the bottom edge touched the tip of the middle finger of the upraised hand and then was anchored in place. After moistening his fingers on a dampened towel, the subject assumed a semisquat position so as to form a right angle between the leg and thigh at the knee joint and between the thigh and trunk at the hip. He then jumped upward reaching as high as possible with the preferred arm and slapping the chalk board with the moistened fingers.

The subject was allowed one practice trial and then two trials in succession for record. The score was the better of the two trials measured to the nearest one-half inch. The reliability coefficient for this procedure was .95.

Power of Arm (Figures 15 and 16, Page 45). The distance an object will travel in flight depends on the angle of release as well as the force applied. To ensure a constant angle of release, the ball was projected by means of a lever type catapult. A light board 34 inches long, 3 inches wide, and 1 3/8 inches thick was hinged at one end to a table 44 feet from the floor. On the other end of the board was fastened a cup-shaped receptacle from which the ball was projected. A handle was placed on the middle and on the side of the board opposite from the receptacle so that the subject might grasp it to project the ball.

To take the test, the subject sat in a semireclining position position with the shoulder of the preferred arm securely anchored to a back rest. While grasping the handle, the arm was fully flexed to bring the catapult back and down to the starting position. A softball was placed in the receptacle, and the subject then extended the arm forcefully, projecting the ball upward and forward at an angle of 45 degrees.

After two practice trials, the subject was given four official trials. Measurements were taken to the nearest inch, and the score was the average of the middle two trials. The reliability coefficient of .95 by this procedure was higher than that obtained in using the average of all four trials of the best of four.

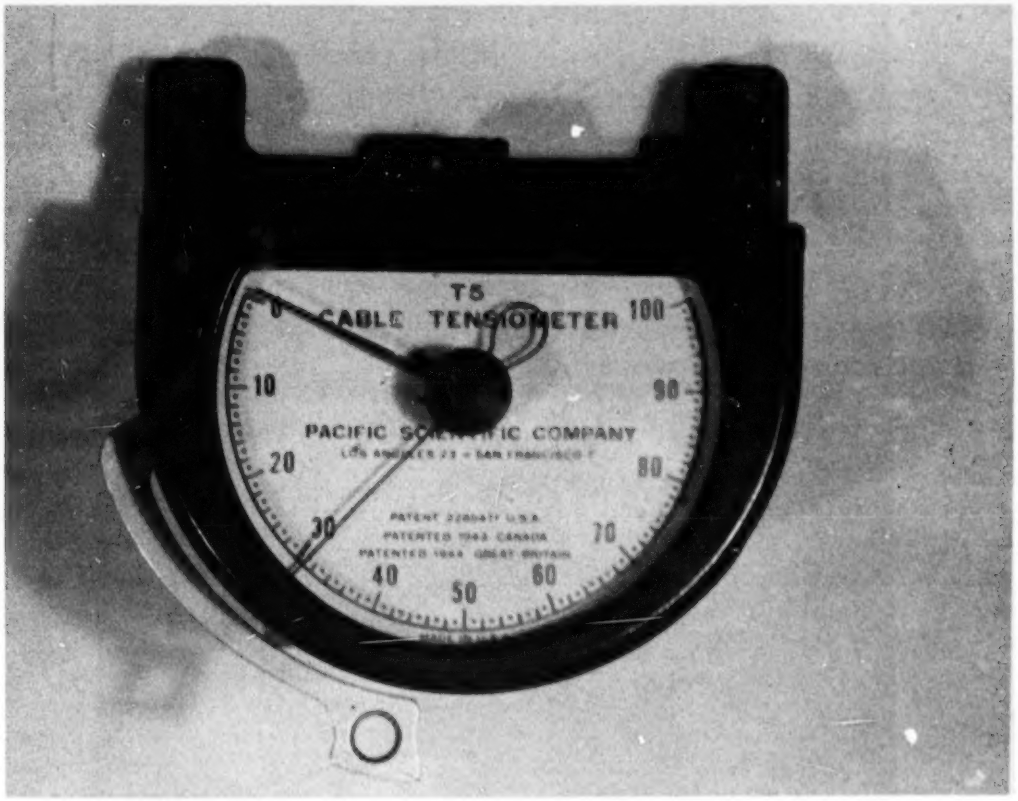

T5
CABLE TENSIOMETER
PACIFIC SCIENTIFIC COMPANY
0
10
20
30
40
50
60
70
80
90
100

Figure 1. Cable Tensiometer

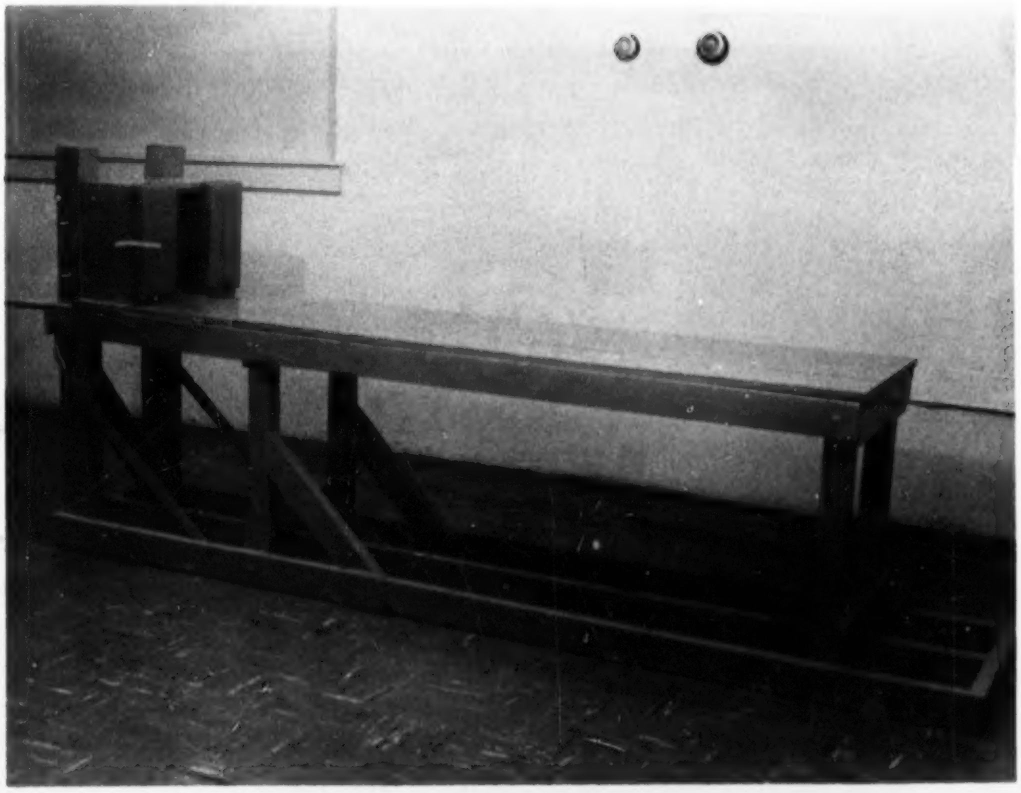


Figure 2. Strength Table

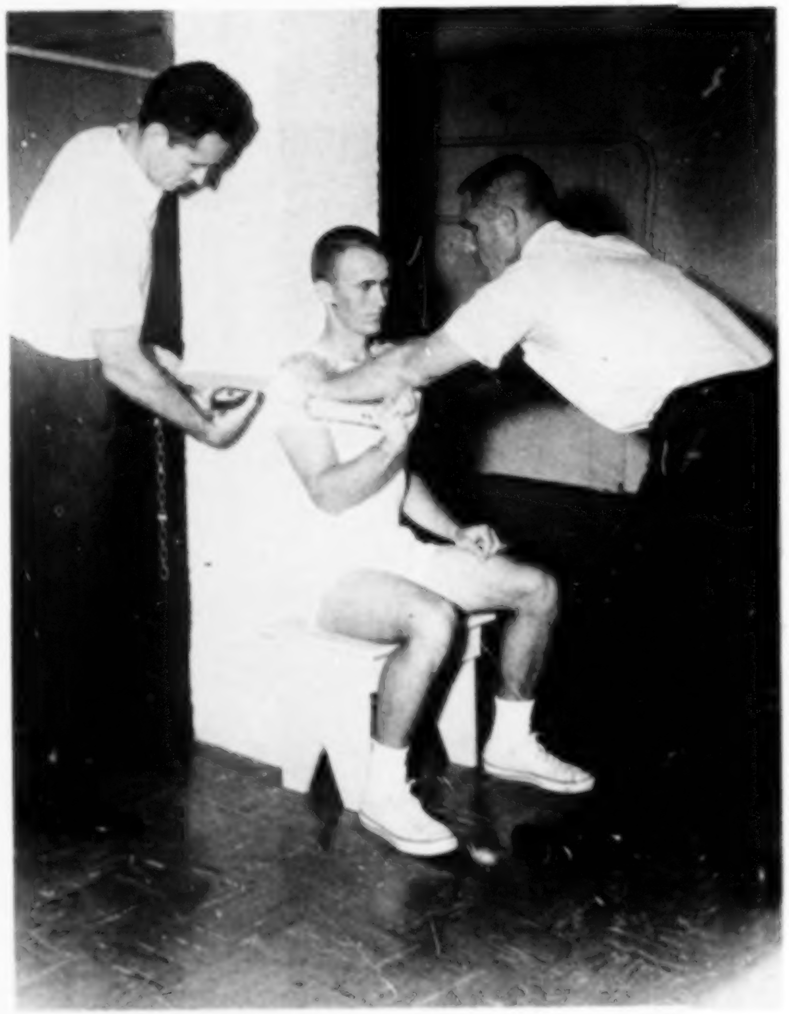


Figure 3. Arm Strength Test

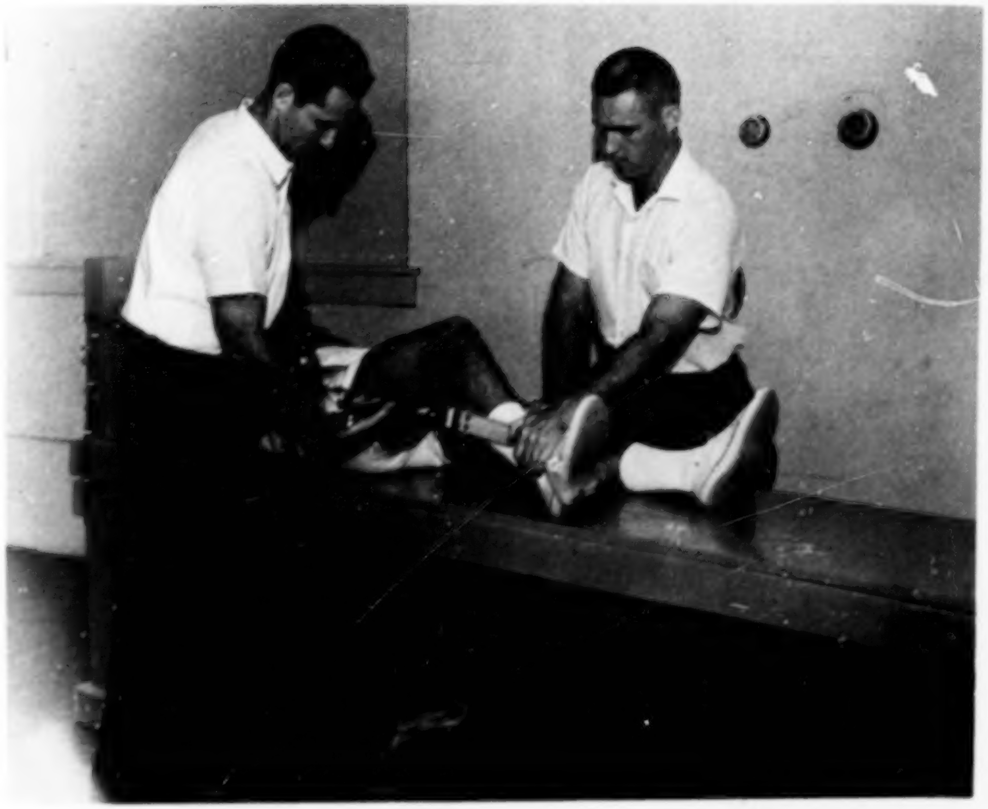


Figure 4. Leg Strength Test

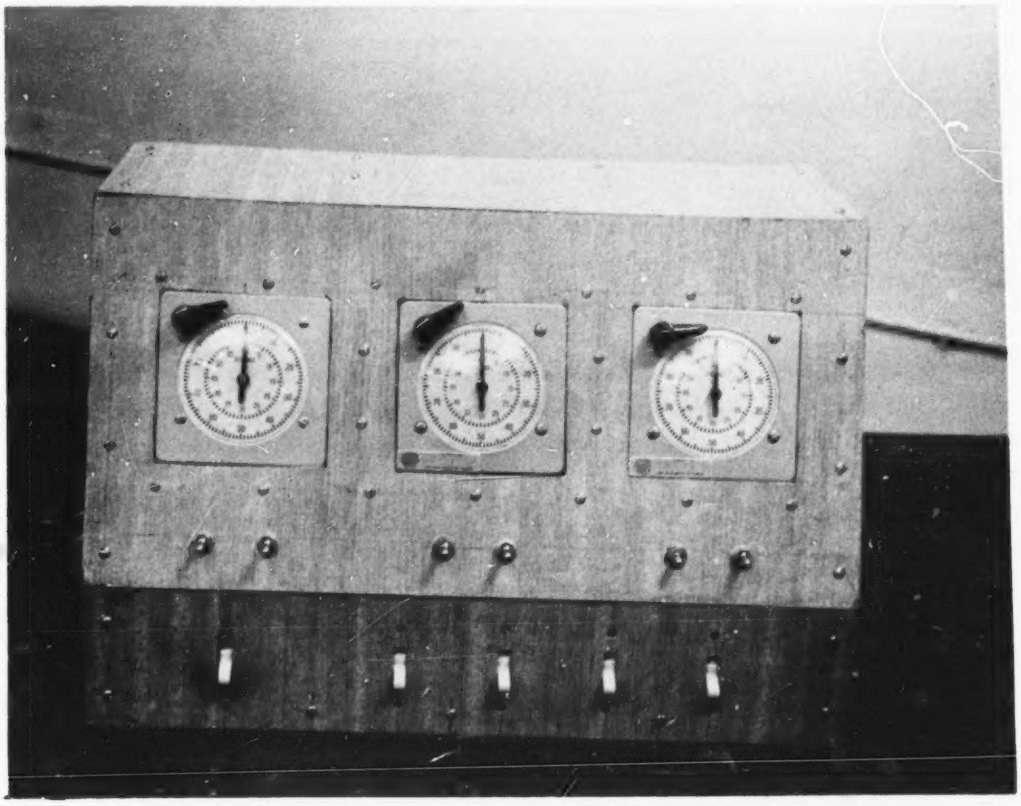


Figure 5. Electric Chronoscopes

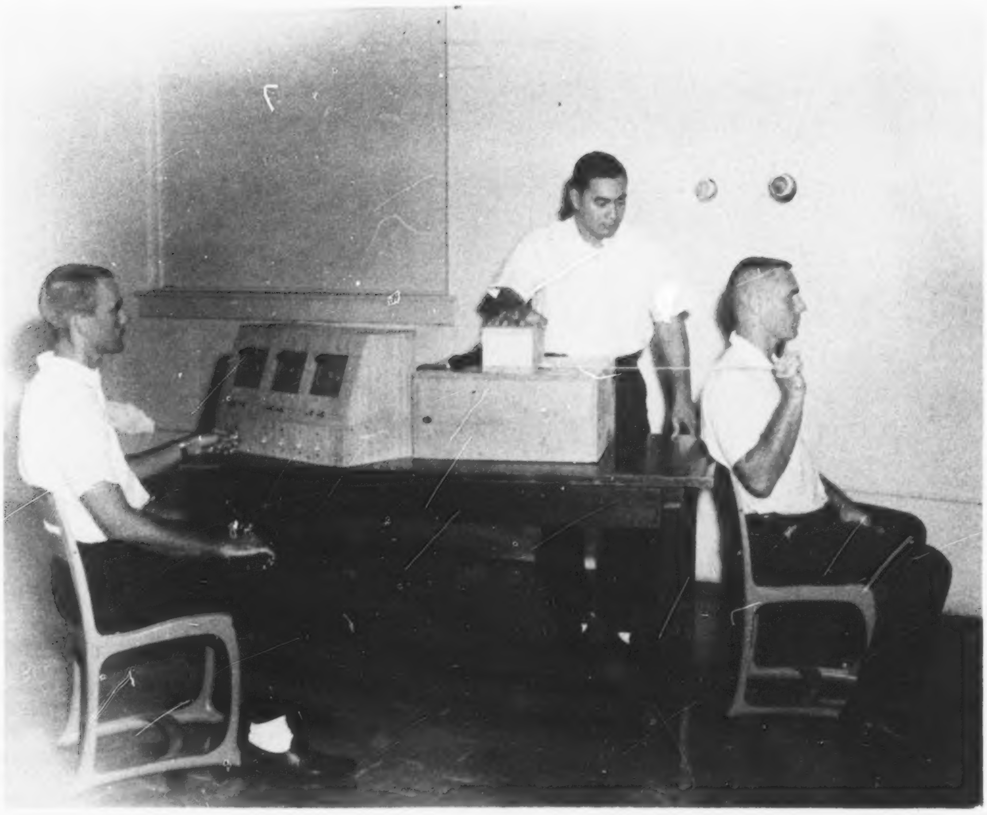


Figure 6. Arm Speed Test

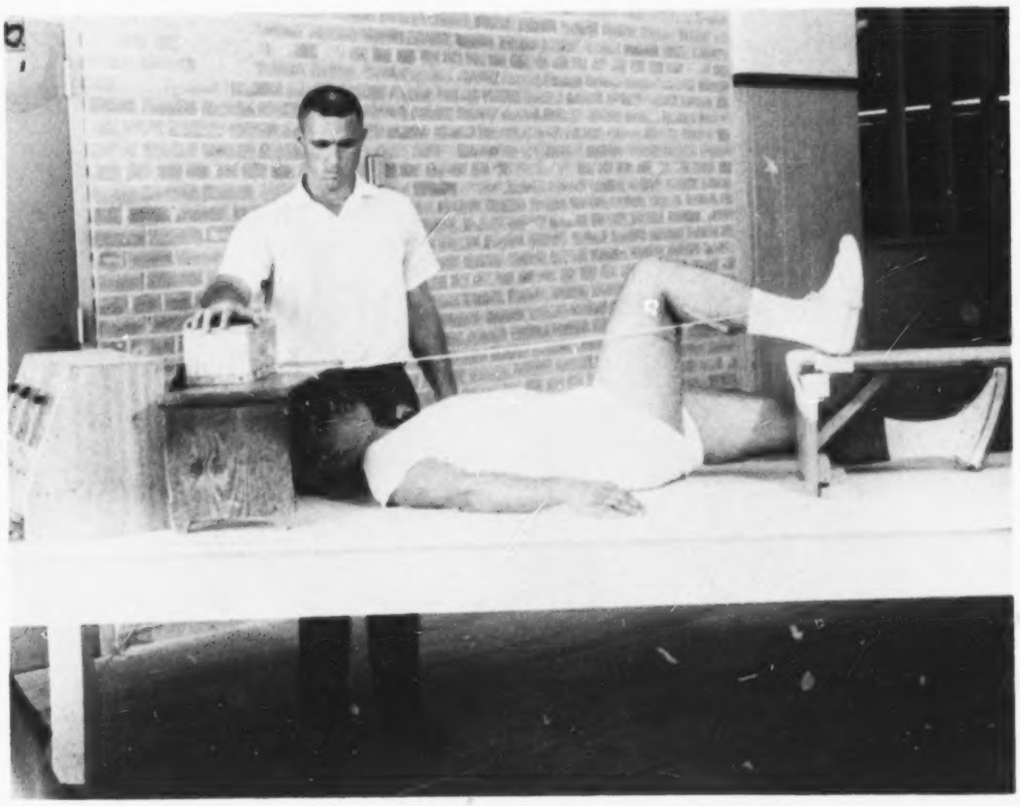


Figure 7. Leg Speed Test

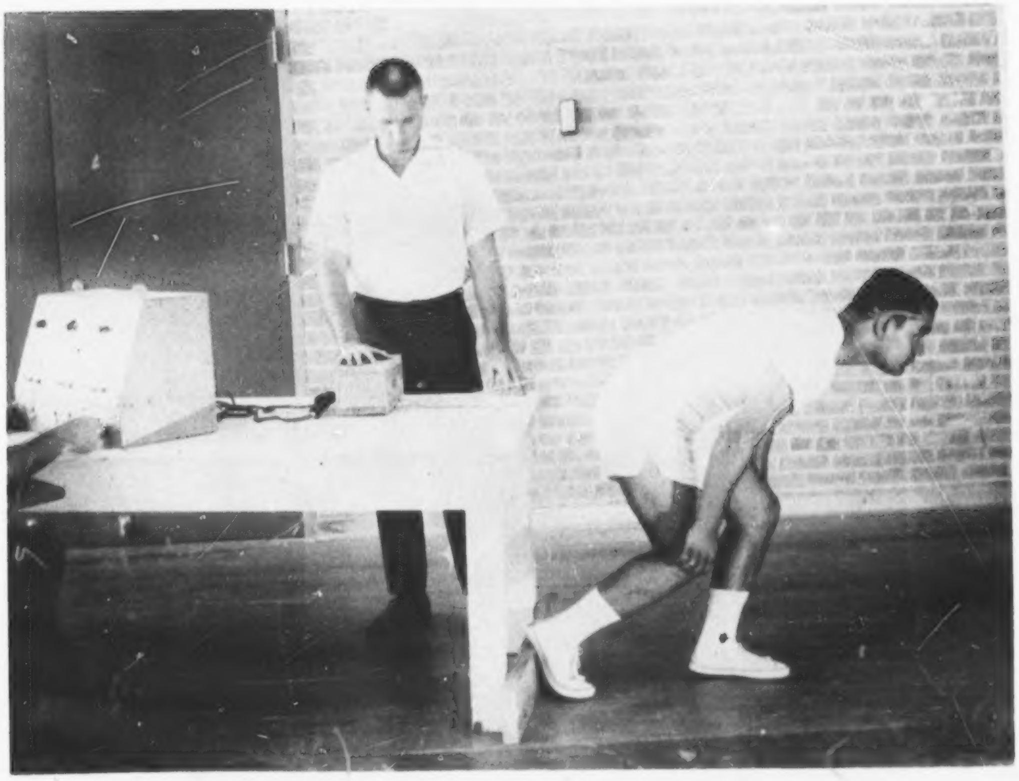


Figure 8. Starting Speed Test

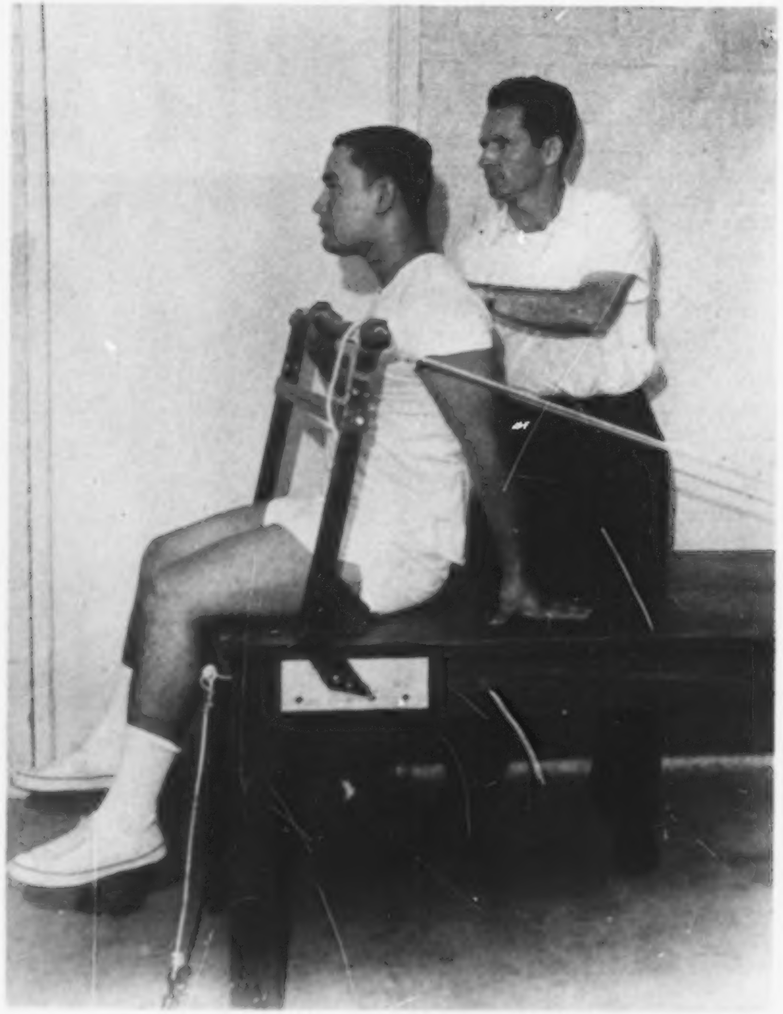


Figure 9. Arm Endurance (Starting Position)

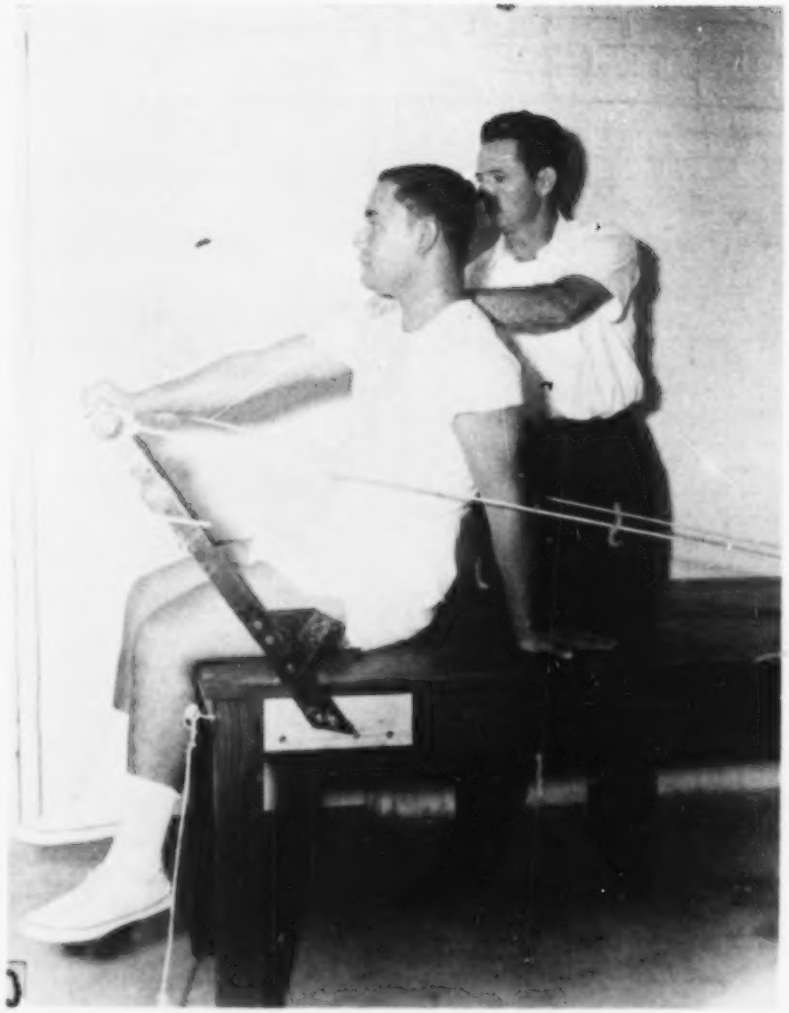


Figure 10. Arm Endurance (Movement Position)

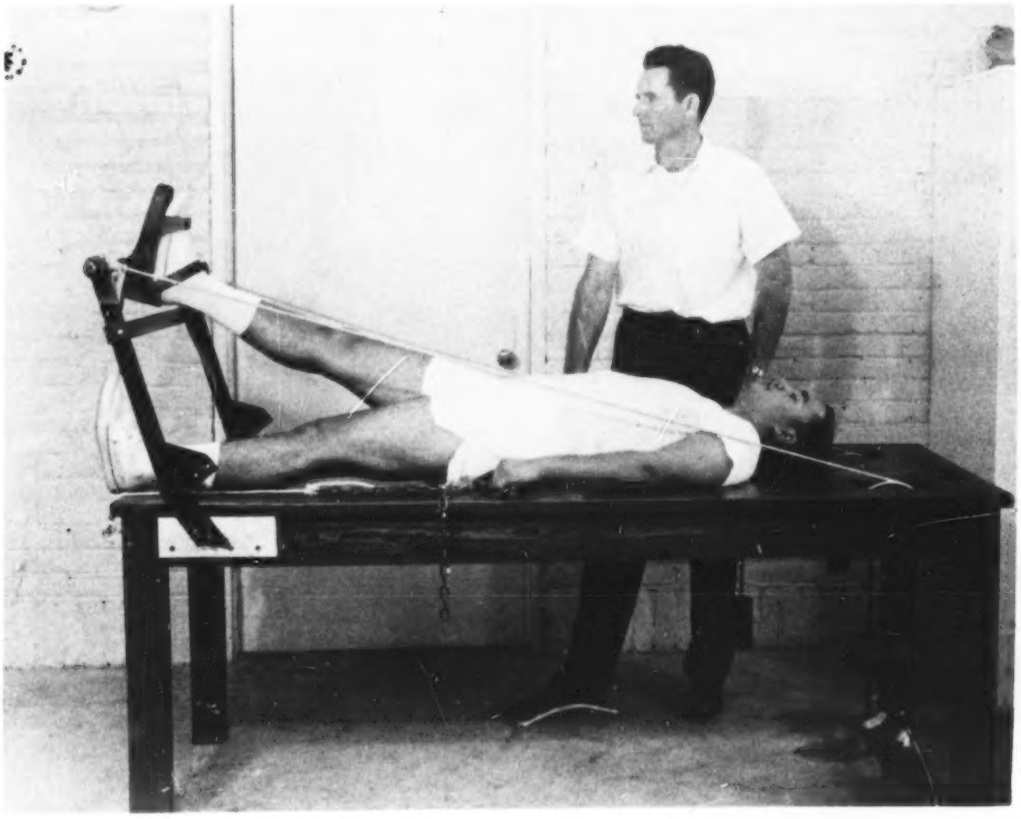


Figure 11. Leg Endurance Test

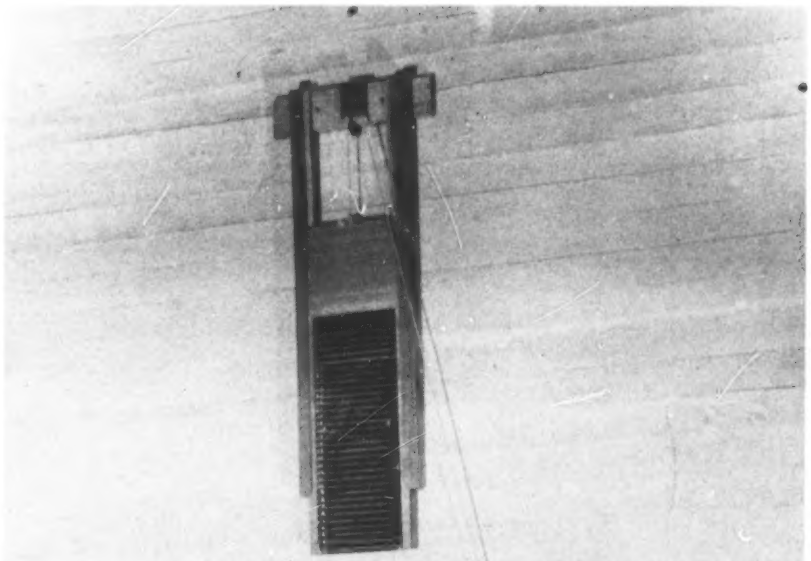


Figure 12. Jump and Reach Board

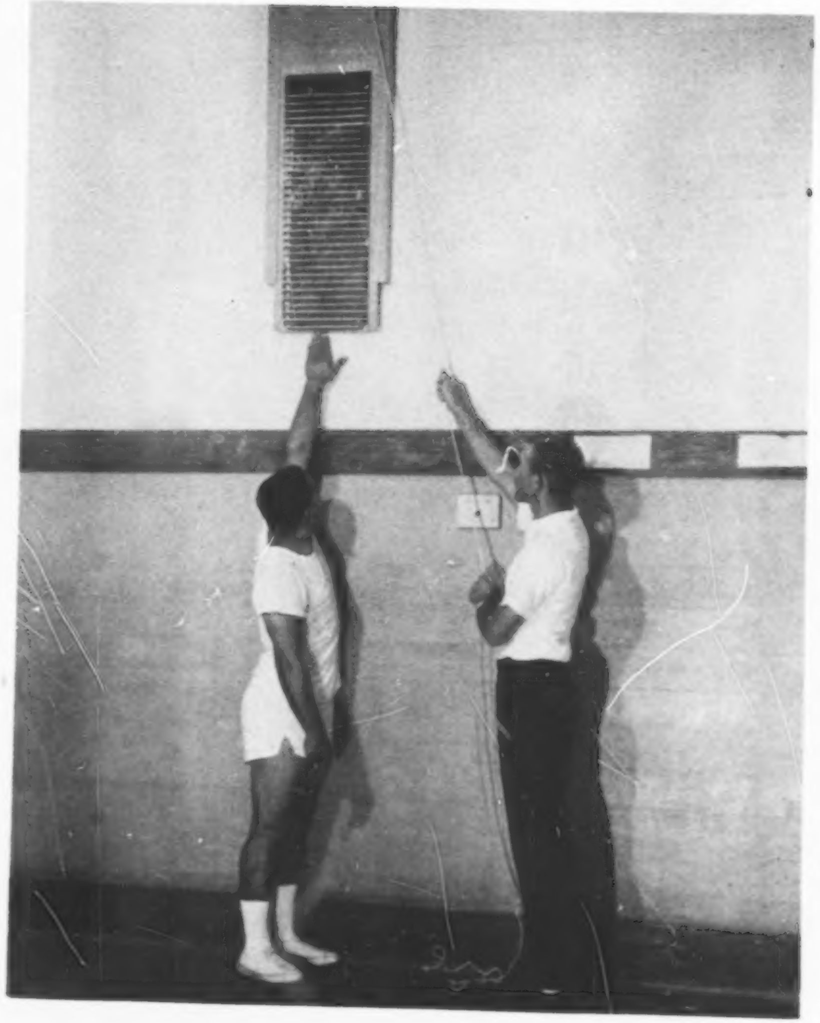


Figure 13. Leg Power Test (Measuring Position)

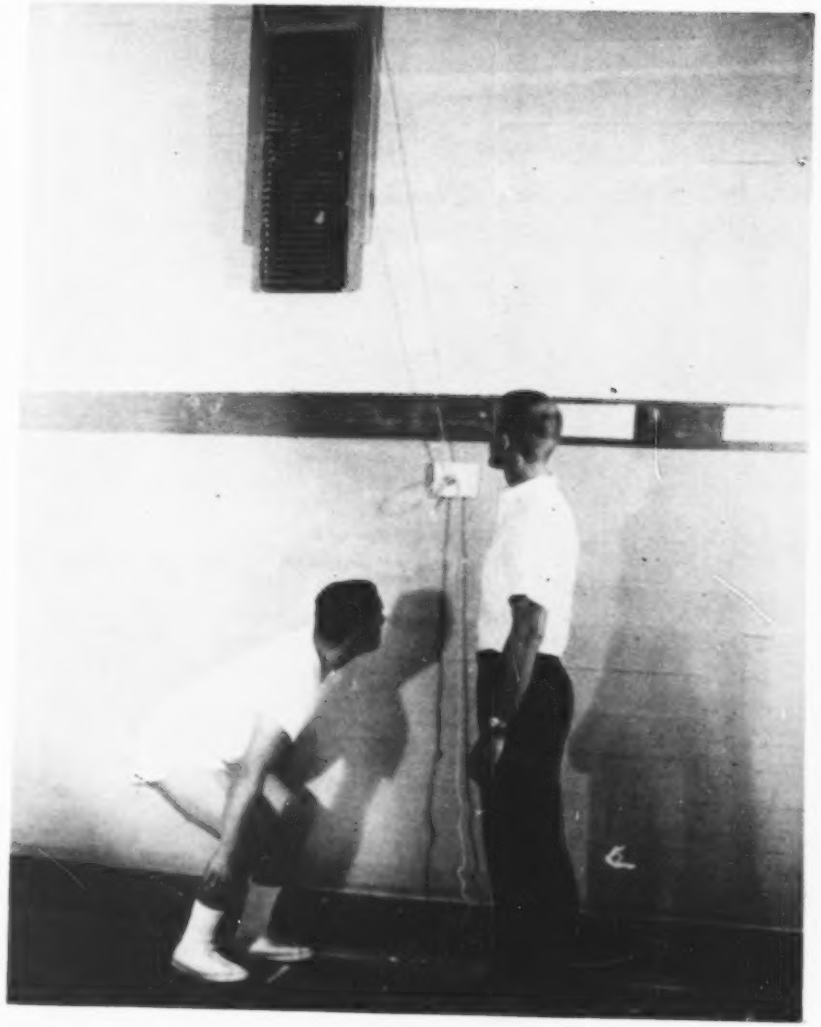


Figure 14. Leg Power Test (Jumping Position)

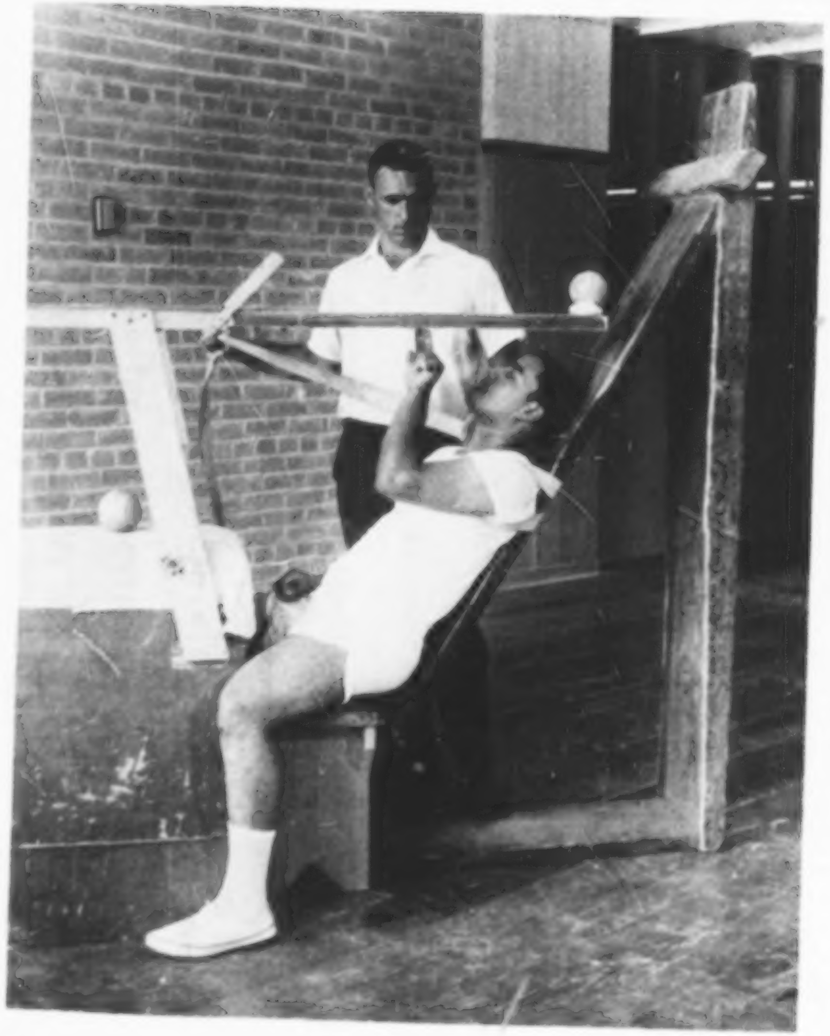


Figure 15. Arm Power Test (Starting Position)

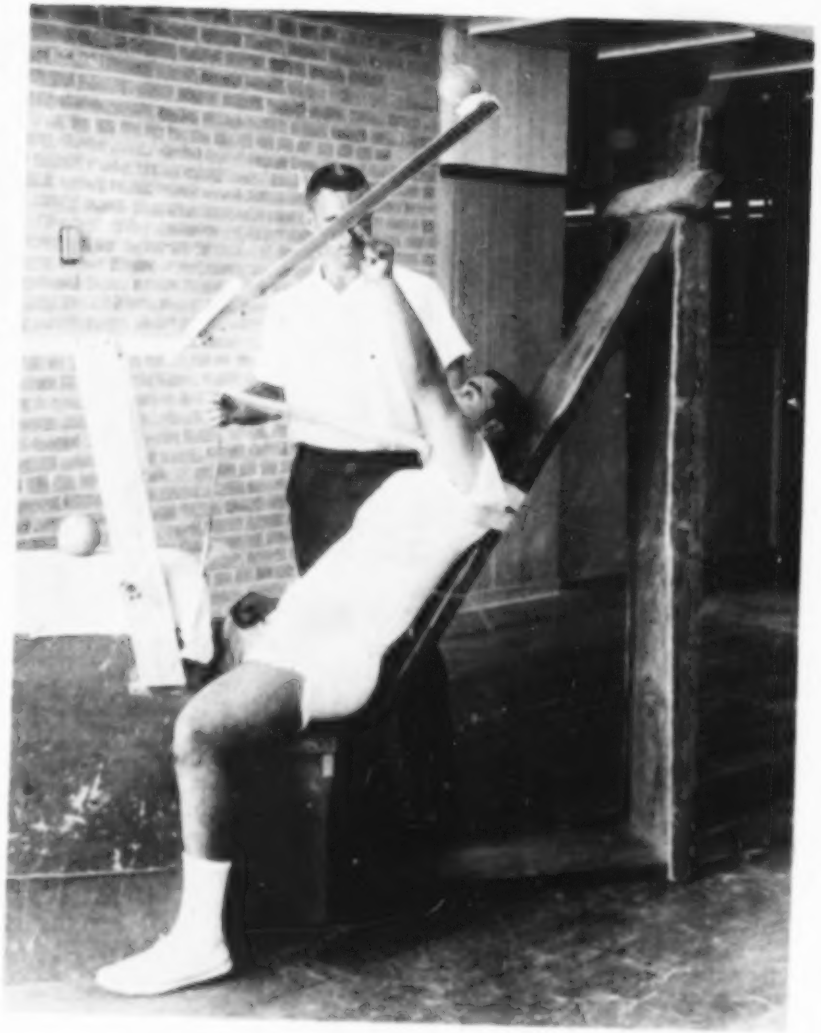


Figure 16. Arm Power Test (Movement Position)

Exercise Programs

Although coaches and physical educators routinely designate weight training programs as isotonic or isometric, these terms were used first by physiologists to classify the contraction of a muscle fiber. Isometric contraction applies to the development of muscle tension without a change in the length of the fibers. This type of contraction is exemplified in pushing against an immovable object or striving to lift a weight that is beyond one's capacity. A contraction of the muscle which results in a change in the length of its fibers is called isotonic. This contraction is further designated as concentric when the muscle shortens as in lifting a weight or eccentric which signifies a lengthening of fibers when a weight is lowered.

The types of muscle contraction described above were used in two of the exercise programs in this study. In the isotonic exercises the subject lifted and lowered relatively heavy weights at a moderate rate of speed. The isometric exercises were performed by contracting the muscle against resistance provided by a strap especially designed to immobilize the limb or section of the body. The speed program was basically isotonic but differed in that the movements were performed rapidly against a relatively light resistance.

In each of the programs an attempt was made to develop all muscle groups in the body rather than to limit exercises to those muscles upon which measurements of strength, speed, endurance, and power were obtained. Insofar as possible the exercises were given in the same manner in each of the programs except for the variation of movement. For example, the isotonic bench press, the isometric push-out, and the speed push-ups, all were designed to develop the extensor muscles of the forearm and the flexor muscles of the arm as in thrusting the entire arm straight forward.

The subjects in each program were continually urged to put forth maximum effort. This was done to ensure optimum results from each exercise rather than to obtain uniformity in the quantity of work done. Inasmuch as the programs varied in the amount of movement, there would logically be considerable differences in muscular activity.

Isotonic Exercises

The progressive resistive procedure was followed in the isotonic program. By this method additional weights were added as the muscles increased in strength. The exercise movements were performed on a basis of five to eight repetitions for one set. In other words, the weight selected for the movement was that which the subject could lift five times correctly with good form. He continued with this weight during each workout until he could execute eight repetitions. The weight was then increased so as to reduce the number of repetitions to five. Presented hereinafter are the directions for the isotonic exercises.

1. Bench Press -- arm flexion and forearm extension.

   Position: Supine on bench, feet flat on floor. Bar bell in chest rest position, pronated grip.

   Movement: Press weight directly upward until arms are fully extended. Lower weight to chest rest position.

2. Leg Press -- thigh extension and leg extension.

   Position: Supine on leg press bench, legs flexed and feet on bar in position to press directly upward.

   Movement: Press weight directly upward until legs are fully extended. Lower weight to starting position.

3. Upright Rowing -- forearm flexion and arm abduction.

   Position: Stand erect with bar bell in thigh rest position. Grasp bar with hands about eight inches apart, pronated grip.

   Movement: Lift bar straight up until it touches the chin. Lower bar to starting position. Keep head up and chest high.

4. Bent Rowing -- forearm flexion, arm extension, scapular adduction.

   Position: Stand with feet apart and toes near bar. Body flexed at hip so trunk is parallel with floor. Trunk and legs straight, head up. Grasp bar with hands at shoulder width, pronated grip.

   Movement: Pull bar straight up until it touches the chest. Lower bar to starting position.

5. Two Arm Curl -- forearm flexion.

   Position: Stand erect with bar bell in thigh rest position. Grasp bar with hands shoulder width apart, supinated grip.

   Movement: Lift bar to shoulders by flexing the forearms. Lower bar to starting position. Keep elbows fixed to sides throughout the movement.

6. Shoulder Shrug -- shoulder elevation.

Position: Stand erect with bar in thigh rest position. Grasp bar with hands shoulder width apart, pronated grip.

Movement: Raise bar by elevating shoulders, attempting to touch the points of shoulders to the ears. Lower bar to starting position.

7. Sit-Ups (Bent Leg) -- trunk flexion.

Position: Supine on floor with legs flexed, heels close to buttocks. Clasp weight plate to back of head.

Movement: Curl head forward and then raise upper back off floor. Bend forward touching chest to knees. Return to starting position.

8. Bent Arm Pull-Over -- forearm extension and arm extension.

Position: Supine on bench with chest and hips stabilized. Bar bell in chest rest position, pronated grip.

Movement: Lower bar back directly behind the head keeping elbows bent. Lower bar as far as is comfortably possible. Pull weight up and forward to starting position, keeping the arms bent, bar just clearing the face.

9. Dead Lift (Knees Bent) -- trunk extension.

Position: Stand crouched with knees and hips slightly flexed, head up. Grasp bar with hands at shoulder width.

Movement: Straighten knees and hips and come to erect stance with bar bell in thigh rest position. Flex knees and hip and lower bar to starting position.

Isometric Exercises

In the isometric exercises the subject contracted the muscles to the maximum or near maximum against an immovable resistance. As previously indicated, this resistance was provided by a strap with which the limb or part of the body was held stationary. Each exercise was performed at one position, and the contraction was held for six seconds. All exercises were performed once during each workout period. The directions used for the isometric exercises are presented below.

1. Push-out -- arm flexion and forearm extension.

   Position: Sit on floor with back against stall bar and legs straight out in front, slightly spread. Strap around rung in stall bar at shoulder height. Place hand in strap loops, palm out so arm is flexed to about 100 degrees at elbow.

   Movement: Push straight out against strap. Repeat with opposite arm.

2. Half-Squat -- thigh extension and leg extension.

   Position: Stand with toes in each of two end loops of strap, feet about 12 inches apart. With body flexed at hips and knees, bring strap up between knees and place around hips. Place hands on knees.

   Movement: Attempt to straighten the legs while coming up on the toes.

3. Upright Rowing -- forearm flexion and arm abduction.

   Position: Stand erect with feet about 12 inches apart and in the end loops of the strap. Grasp middle of strap in front of body, pronated grip.

Movement: Pull up with both hands, keeping elbows out and hands near abdomen.

4. Bent Rowing -- forearm flexion, arm extension, scapular adduction.

Position: Stand with feet about 12 inches apart and in the end loops of strap. Body flexed at hips so trunk is parallel with floor. Trunk and legs straight, head up. Grasp strap with right hand in first loop above right foot and with left hand in first loop above left foot, pronated grip.

Movement: Pull up by attempting to raise the hands to the chest.

5. Two Arm Curl -- forearm flexion.

Position: Stand erect with feet about 12 inches apart and in the end loops of strap. Grasp strap slightly below level of waist with hands shoulder width apart, supinated grip.

Movement: Pull up by attempting to raise the hands to the shoulders. Keep elbows fixed to sides during exertion.

6. Shoulder Shrug -- shoulder elevation.

Position: Stand erect with feet about 12 inches apart and in the end loops of strap. With arms fully extended, grasp strap with hands shoulder width apart, pronated grip.

Movement: Pull up by attempting to raise the shoulders. Keep arms straight and close to sides during exertion.

7. Sit-Ups (Bent Leg) -- trunk flexion.

Position: Supine on floor with legs flexed, heels close to buttocks. Place strap across chest with ends held by individuals on either side. Another person holds feet against the floor.

Movement: Attempt to raise trunk up to sitting position.

8. Bent Arm Pull-Over -- forearm extension and arm extension.

Position: Stand erect with feet about 12 inches apart. Place strap around back at shoulder level. With arms flexed at right angles at elbow, place hands shoulder width apart in loops of strap, pronated grip.

Movement: Pull forward and downward attempting to straighten the arms.

9. Dead Lift -- trunk extension.

Position: Stand with feet about 12 inches apart and in the end loops of the strap. Body flexed at hips so trunk is parallel with floor. Trunk and legs straight, head up. Place middle of strap over head and behind neck.

Movement: Pull up with head attempting to raise trunk to erect position.

Speed Exercises

In the speed method, the individual performed the exercises as rapidly as possible within a prescribed period of time. The time interval in most instances was 10 seconds. During the first two weeks of the program, the subject executed two sets or bouts of each exercise. The sets were increased as the physical condition improved so that the subjects were performing five and six sets of each exercise by the end of the semester. A 10-second rest period was allowed between sets of a single exercise with a 60-second rest between exercises. Presented hereinafter is the ten-week progression of time intervals and sets followed by a description of exercises.

Ten Weeks Progression of Sets and Time Intervals

	1-2 Weeks		3-4 Weeks		5-6 Weeks		7-8 Weeks		9-10 Weeks	
	Sets	Sec.	Sets	Sec.	Sets	Sec.	Sets	Sec.	Sets	Sec.
Push-Ups	2	10	3	10	4	10	5	10	6	10
Jump and Reach	2	10	3	10	4	10	5	10	6	10
Pull-Ups	2	10	3	10	4	10	5	10	6	10
Sit-Ups	2	10	3	10	4	10	4	15	5	15
Back Raise	2	10	3	10	4	10	4	15	5	15
Charger	2	10	3	10	4	10	5	10	6	10

1. Push-Ups -- arm flexion and forearm extension.

   Position: Prone on floor with trunk and legs straight. With arms flexed at elbows, place hands palm down on floor shoulder width apart. Thumbs are in position underneath point of shoulder and fingers extend forward.

Movement: Push up until arms are fully extended, supporting body on hands and toes. Keep trunk and legs straight. Return to starting position.

2. Jump and Reach -- thigh extension and leg extension.

Position: Stand with feet slightly apart and body flexed at right angles at hips and knees. Extend arms back and down with palms in.

Movement: Jump upward by swinging arms up and extending the legs forcibly. Return to starting position.

3. Pull-Ups -- forearm flexion, arm extension, scapular adduction.

Position: Supine on floor with trunk and legs straight. Clasp hands of partner who stands astride chest of subject.

Movement: Pull up until chest touches thighs of partner. Keep trunk and legs straight. Return to starting position.

4. Sit-Ups (Bent Leg) -- trunk flexion.

Position: Supine on floor with legs flexed, heels close to buttocks. Clasp hands behind head. Partner holds feet against floor.

Movement: Sit up bringing the chest as near the knees as possible. Return to starting position.

5. Back Raise -- trunk extension.

Position: Prone on floor with trunk and legs straight. Clasp hands behind head.

Movement: Raise head, shoulders, and legs from floor simultaneously. Return to starting position.

6. Charger -- thigh flexion and extension, leg flexion and extension.

Position: Front leaning rest position supporting body on hands and feet. Arms and trunk straight with left leg flexed bring knee up under chest and right leg fully extended.

Movement: Reverse position of feet by simultaneously extending left leg backward and flexing right leg bringing right knee up under chest. Keep trunk straight and buttocks low during execution.

III. FINDINGS

Comparison of Treatment Effects

The primary purpose of this study is to determine the effectiveness of the three methods of resistive exercises in developing muscular strength and endurance. Considered also are the effects of the exercises on the speed and power of the muscles. The comparison of the three methods is based on the scores obtained on a pre-test and a post-test on each of the tests described in the preceding section. The multiple linear regression technique for variance analysis is used to examine the data obtained from these tests. The regression models followed in the analysis are described by Bottenberg and Ward (7:76-95) for ascertaining treatment effects in the presence of concomitant variables. These regression models are analogous to the typical covariance analysis for studying the effects of treatments on subjects having considerable variation on initial status. The treatment effects in this study are reflected in the post-test scores. The pre-test scores constitute the concomitant variables. The data were analyzed through use of the facilities of The University of Texas Computation Center following programs proposed by Ward (62:226-236).

Multiple Linear Regression Technique

No attempt is made to outline in detail the regression models for the covariance analysis. A full explanation of these and other models is presented by Bottenberg and Ward (7). It does seem appropriate, however, to describe briefly the multiple linear regression technique as applied to the analysis of the data in this study.

Just as any variance analysis, the multiple linear regression technique is based on the concept of "error sum of squares." In its simplest form, the linear regression equation involves one dependent and one independent variable as exemplified in the following formula:

$$Y = a_o + a_1X + E$$

where Y is the dependent variable,

X is the independent variable,

a_o and a_1 are constants (least squares weights), whose values are such as to produce the minimum error sum of squares,

E is an index of the error in predicting Y from X.

This formula can be extended for an indefinite number of variables so that:

$$Y = a_o + a_1X_1 + a_2X_2 + a_3X_3 + \ldots\ldots\ a_nX_n + E$$

where n is the number of variables.

Such a formula includes complete categorized information for all subjects under consideration and would be designated as the full or unrestricted model. One can compare the efficiency of prediction for various sets of independent variables by computing the F-ratios from their error sums of squares. It is also possible to compare the efficiency of prediction of a sub-set of predictors (restricted model) with the full model. The F-ratio yielded by the following formula would indicate whether or not there is a significant gain in prediction efficiency by having full knowledge of all categorical information included in the full model:

$$F = \frac{(ESS_r - ESS_f) / df_1}{ESS_f / df_2}$$

where ESS_f is the error sum of squares for the full model,

ESS_r is the error sum of squares for the restricted model,

df_1 is the degrees of freedom number one or number of unknowns (constant weights) in the full model minus the number of unknowns in the restricted model,

df_2 is the degrees of freedom number two or number of subjects minus the number of unknowns in the full model.

The computer program for the linear regression analysis yields a multiple R and a multiple R^2 rather than the error sum of squares (ESS). Inasmuch as there is a direct inverse relationship between the ESS and the R^2, the F-ratio may be computed by use of the following formula:

$$F = \frac{\left[(R_f)^2 - (R_r)^2\right] / df_1}{\left[1 - (R_f)^2\right] / df_2}$$

where $(R_f)^2$ is the squared multiple R of the predictors with the dependent variable in the full model,

$(R_r)^2$ is the squared multiple R of the predictors with the dependent variable in the restricted model.

In its simplest form, the linear equation is

$Y = a_0 + a_1 X$

where X and Y are the two variables whose relationship are being studied.

Such an equation may also be expressed in graphic form as exemplified in Figure 17, Page 63. In this graph the X axis represents the range of scores on variable X, while the scores on variable Y are projected on the Y axis. The X and Y variables in this study are the pre-test and post-test scores respectively. If one were to plot the scores made by each subject on X and Y for a particular test, it would be possible to draw a line that would best represent these plotted points. This line is called the "regression line" and is represented by the slanting line om in Figure 17. The regression line crosses the Y axis at a_o as in the preceding formula which in this instance is o on the graph. The slope of the line is represented by a_1 in the formula or mn divided by on on the graph. Knowing a_o and a_1, it is therefore possible to predict Y from any value of X. The error sum of squares computed in the linear regression procedure is at a minimum when attempting to predict Y from X. Thus the constants a_o, a_1, . . . a_n are often called "least squares weights."

The graph in Figure 17 illustrates the relationship between a pair of variables, e.g. the pre-test and post-test scores on a specific test. It is also possible to observe the relationships among several pairs of variables simultaneously. For example, the graphs in Figures 18, 19, and 20, Page 63, might represent the regression lines drawn from the pre-test and post-test scores for the isotonic (I), isometric (II), and speed (III) groups. All three regression lines could be drawn on a single graph as shown in Figure 21.

In analyzing treatment effects, the investigator is concerned with the initial status of subjects as revealed through pre-test scores. In the typical covariance analysis, the influence of initial status is taken into account by comparing the amount of change on the post-test with the amount of change on the pre-test. For example, in Figure 22, Page 63, the unit ab on the X axis (pre-test scores) is projected via the regression line on the Y axis (post-test scores) to form unit cd, which is about one-third as long as the unit ab. In the data represented by this graph, one would expect an increase of one point in score on the post-test for every increase of three points on the pre-test. As revealed in Figure 23, Page 64, another slope for the regression line would result in a different relationship between the units on the X and Y axes.

In considering the effect of initial status as revealed through pre-test scores when comparing three groups in a study, one would hope to obtain regression lines similar to those shown in Figure 21. The problem then becomes one simply of determining if the differences between the lines are significant. When such differences are significant, the conclusion is that the treatment effects differ over the entire range of scores on the X axis. Assuming the differences between regression lines in Figure 21 to be significant, one could recommend isotonic over either isometric or speed exercises and isometric over speed irrespective of the score on the pre-test as a means of developing the attribute under consideration.

The application of the typical analysis of covariance assumes that regression lines such as the three illustrated in Figure 21 have a common slope, i.e. the slopes do not differ significantly. When such assumption is not met, then the square root, logarithmic, or some other transformation should be applied to the data to attempt to obtain regression lines that do have a common slope. In using the multiple linear regression technique for covariance analysis, it is possible to obtain meaningful interpretations when regression lines do not have a common slope.

In Figures 24 and 25, Page 64, are illustrations of a simple two-group problem wherein the regression lines do not have a common slope. In the first instance in Figure 24, it is found that the regression lines cross between the points a and b, which is the range of interest or the limits of scores obtained on the attribute in question. One would conclude that for individuals having pre-test scores lower than m (point of intersection of regression lines) the isotonic exercises are better than the isometric, while the isometric exercises are better for those with pre-test scores higher than m. In Figure 25 the regression lines for Groups I and III cross beyond the range of interest. The conclusion here is that isotonic exercises are better than speed for all subjects, but the advantage of the isotonic movements decreases as the pre-test scores increase. The two examples in Figures 24 and 25 are combined in Figure 26 to illustrate one possible situation for the three-group problem of this study. Obviously with three groups, one might be confronted with many different situations with each requiring its own interpretation. Illustrations of two other possible combinations are presented in Figures 27 and 28.

The models used in the computation of the F-ratios in the multiple linear regression technique for covariance analysis vary considerably according to the results obtained in the computation. However, there is a definite pattern to be followed in computing F-ratios as illustrated by the flow chart in Figure 29, Page 65. As will be noted, each successive step depends on the significance of the F-ratio obtained in the preceding computation. For example, if F_1 is not significant, the conclusion is that the regression lines are parallel or have a common slope, and the next task is to determine if the lines are co-linear, i.e. is there a difference among groups on the attribute under consideration. On the other hand if F_1 is significant, the lines do not have a common slope and the conclusion is that there is a difference among treatment effects. The next task is to determine whether or not there is a significant difference between each pair of lines. Other possible examples will become apparent as the results of this study are discussed.

Results of Analysis

The results of the multiple linear regression analysis for the tests in this study are presented in Tables 1 through 7, Pages 70 through 76, and in Figures 30 through 38, Pages 77 through 85. The data in Tables 1, 2, and 3 are included for information only and do not in themselves provide a basis for interpretation. Tables 4 through 7 contain the appropriate F-ratios together with the multiple R^2,s, and the degrees of freedom used in computing these ratios. The significance levels for the F-ratios are also included in the tables. Although ratios falling below the .05 level are considered not significant (NS), it will be possible in some instances to draw conclusions from them. The F-ratio subscripts correspond to those used in the flow chart of Figure 29.

The graphs in Figures 30 through 38 depict the pattern of the

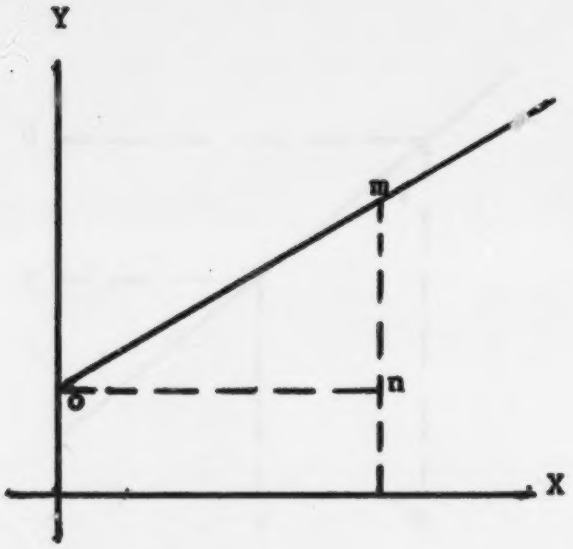


Figure 17

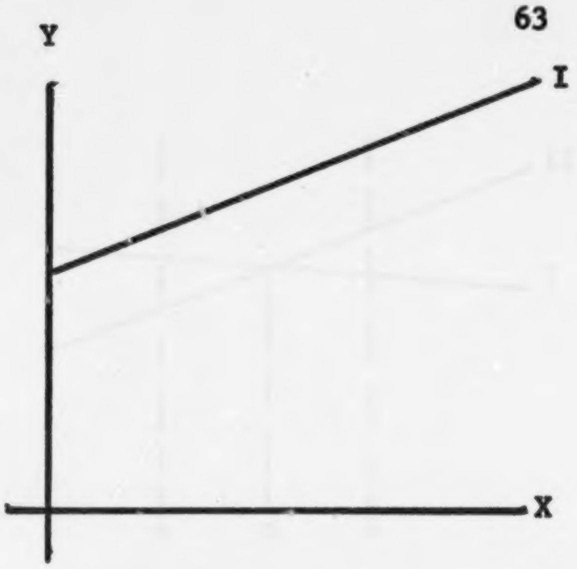


Figure 18

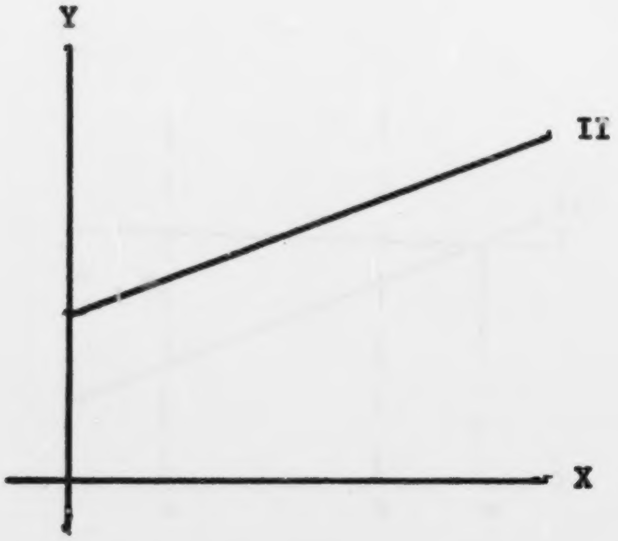


Figure 19

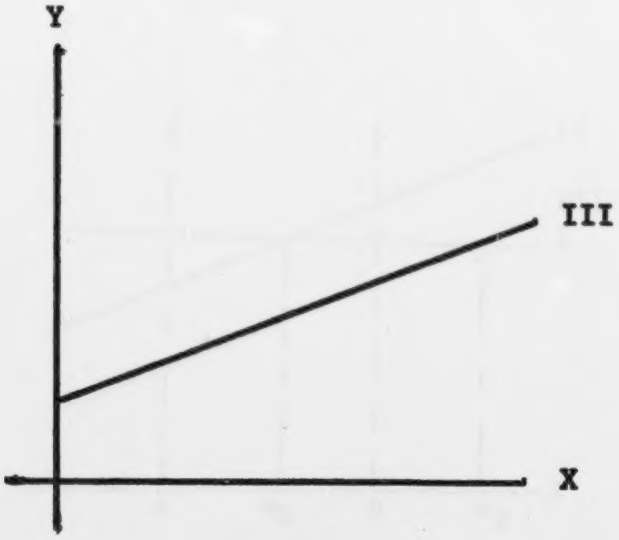


Figure 20

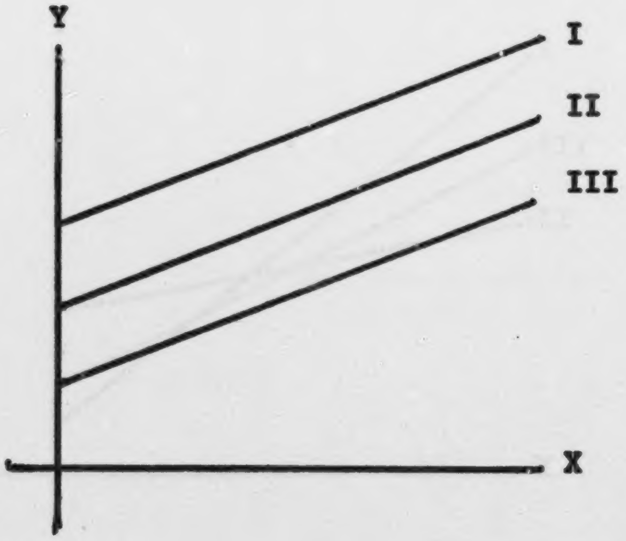


Figure 21

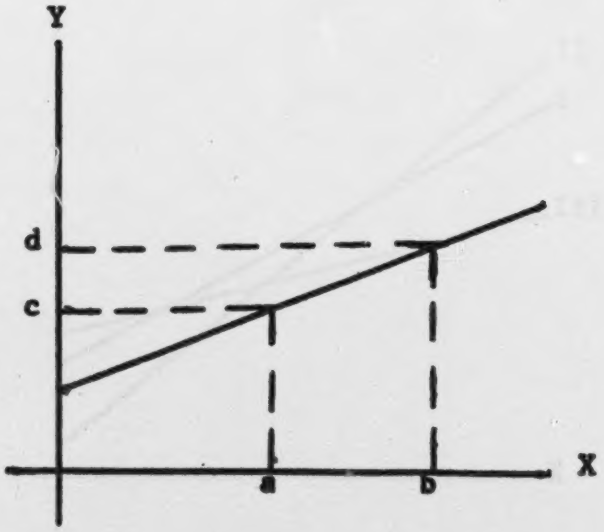


Figure 22

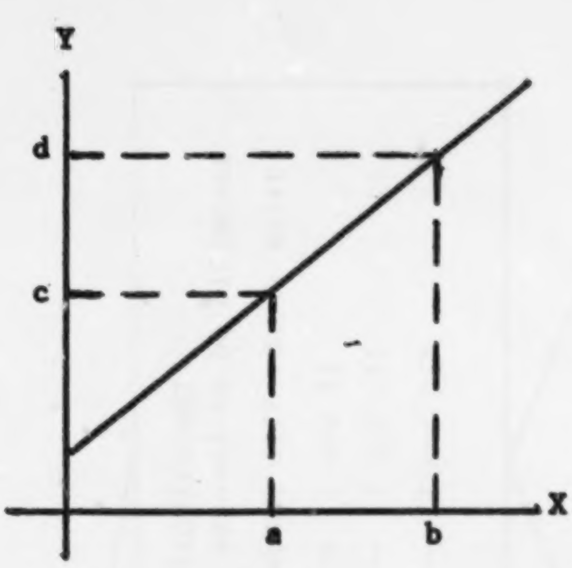


Figure 23

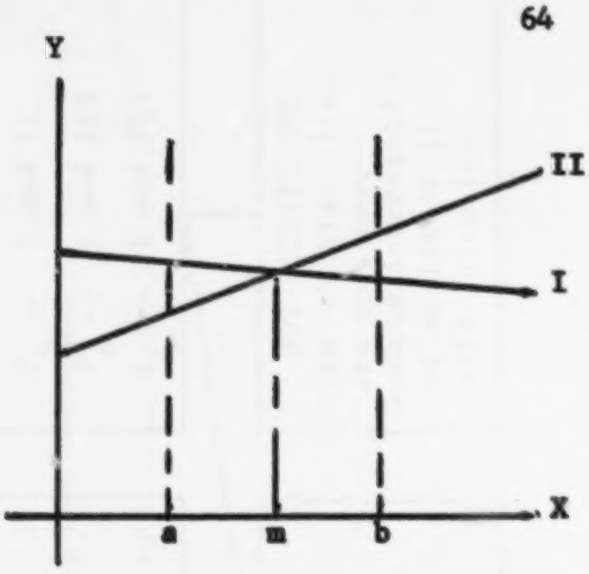


Figure 24

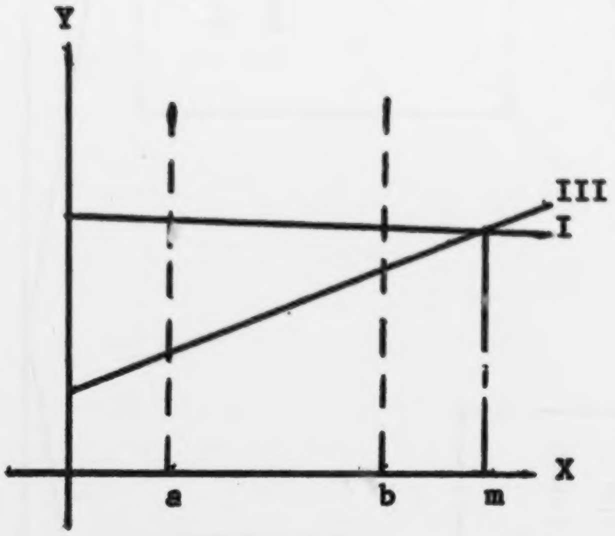


Figure 25

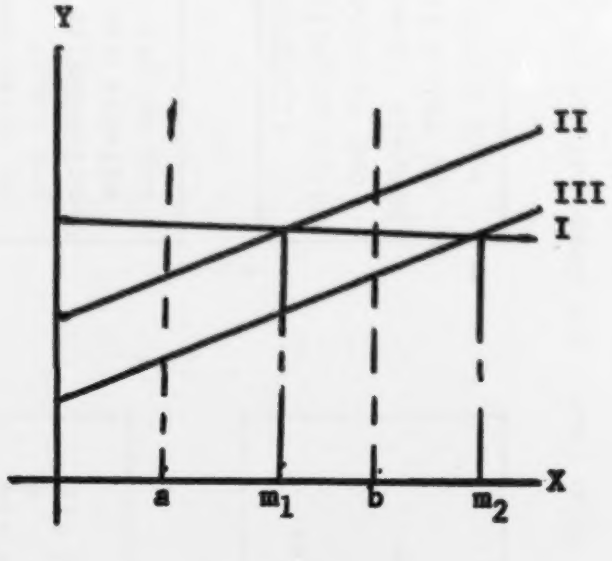

Y
II
III
I
a
m_1
b
m_2
X

Figure 26

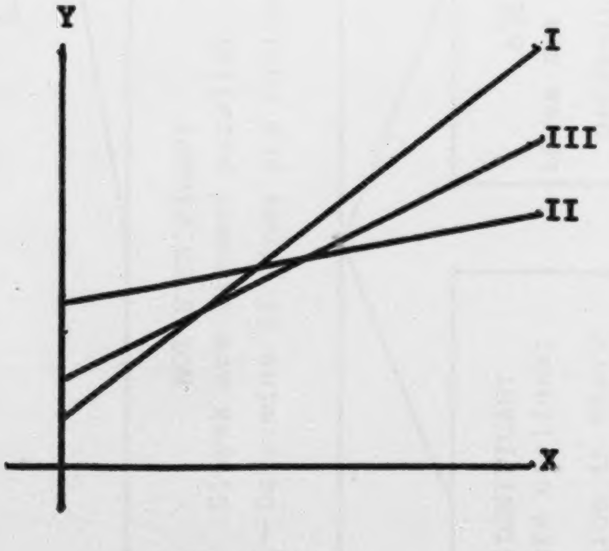


Figure 27

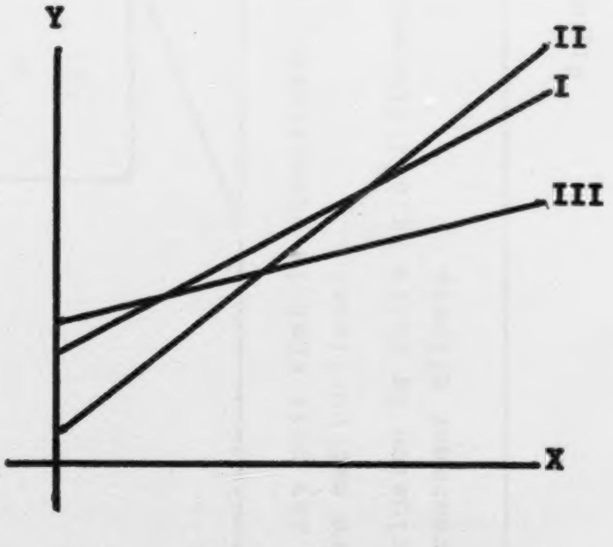


Figure 28

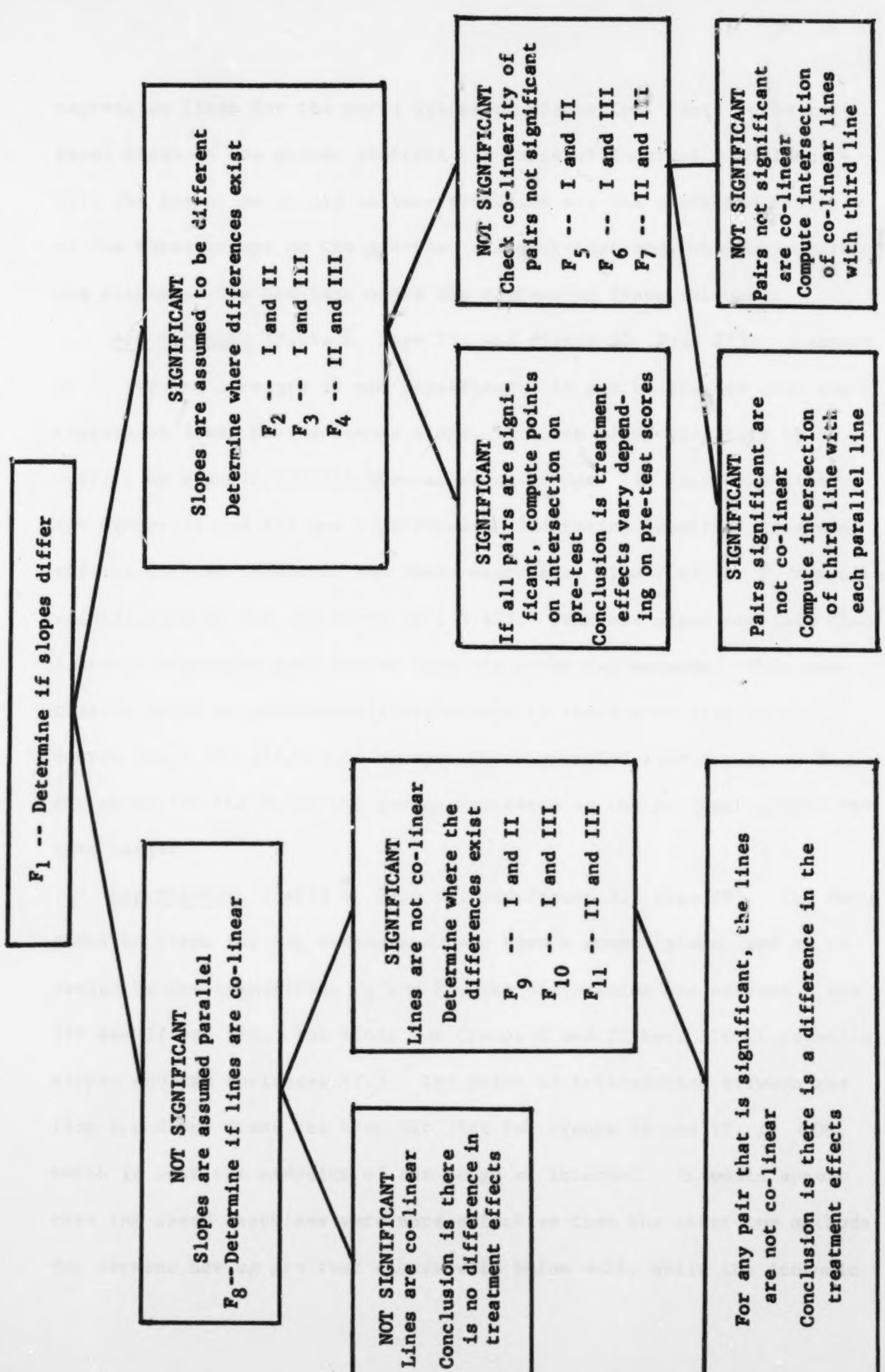

F1 -- Determine if slopes differ
NOT SIGNIFICANT
Slopes are assumed parallel
F8--Determine if lines are co-linear
SIGNIFICANT
Slopes are assumed to be different
Determine where differences exist
F2 -- I and II
F3 -- I and III
F4 -- II and III
NOT SIGNIFICANT
Lines are co-linear
Conclusion is there is no difference in treatment effects
SIGNIFICANT
Lines are not co-linear
Determine where the differences exist
F9 -- I and II
F10 -- I and III
F11 -- II and III
For any pair that is significant, the lines are not co-linear
Conclusion is there is a difference in the treatment effects
SIGNIFICANT
If all pairs are significant, compute points on intersection on pre-test
Conclusion is treatment effects vary depending on pre-test scores
NOT SIGNIFICANT
Check co-linearity of pairs not significant
F5 -- I and II
F6 -- I and III
F7 -- II and III
SIGNIFICANT
Pairs significant are not co-linear
Compute intersection of third line with each parallel line
NOT SIGNIFICANT
Pairs not significant are co-linear
Compute intersection of co-linear lines with third line

Figure 29. Flow Chart for Computation of F-Ratios

regression lines for the three groups on the various tests. The vertical lines on the graphs indicate the range of interest. Included with the graphs as an aid in interpretation are the means and ranges of the three groups on the pre-test and post-test and, when appropriate, the points on the pre-test where the regression lines intersect.

Arm Strength (Table 4, Page 73, and Figure 30, Page 77). Inasmuch as F_1 for arm strength is not significant, it can be assumed that the regression lines have a common slope. A check of co-linearity by F_8 reveals no significant differences among groups. In fact, the lines for Groups II and III are superimposed, indicating identical treatment effects for the isometric and speed exercises. The 2.67 for F_8 approaches significance at the .05 level ($F = 3.11$). Thus one might conclude that isotonic exercises were better than the other two methods. This conclusion would be particularly applicable to those with high initial scores since the difference between the regression line for Group I and those for the other two groups increases as the pre-test scores become larger.

Leg Strength (Table 4, Page 73, and Figure 31, Page 78). The regression lines for leg strength do not have a common slope, and as revealed by the significant F_3 and F_4, the differences are between I and III and II and III. The lines for Groups I and II have almost identical slopes and are co-linear (F_5). The point of intersection between the line for Group I and the best fit line for Groups II and III is 408, which is near the midpoint of the range of interest. It would appear that the speed exercises were more effective than the other two methods for persons having pre-test scores well below 408, while the isotonic and isometric programs were better for those scoring high on the pretest.

Arm Speed (Table 5, Page 74, and Figure 32, Page 79). Inasmuch as the lower scores on the three speed tests indicate better performance, the interpretation of the regression lines will be reversed from that for the other tests. Assuming differences among lines, the best method would be that represented by the line crossing the Y axis at the lowest point. As revealed by F_1 and F_8, the regression lines for arm speed have a common slope and are co-linear. Both ratios are well below the .05 level, indicating no difference in treatment effects.

Leg Speed (Table 5, Page 74, and Figure 33, Page 80). The regression lines for leg strength also appear to have a common slope and are co-linear. However, F_1 approaches significance at the .10 level ($F = 2.39$), suggesting that the treatment effects tended to differ for the three methods. An examination of the graph reveals that the difference is primarily between the isotonic and the other two methods. Inasmuch as the regression lines intersect well within the range of interest, one might conclude that the isotonic program was more effective for those persons who were fast initially and the isometric or speed exercises for those who were slow in movement.

Starting Speed (Table 5, Page 74, and Figure 34, Page 81). With a very low value for F_1, one may conclude that the regression lines for starting speed are parallel. Although F_8 has been designated as not significant, it reaches the limit for the .10 level. The difference is apparently between isotonic and the other two methods since the regression lines for the latter are superimposed. Furthermore, the lines intersect beyond the range of interest so that the differences between isotonic and the other two methods increase for subjects with slower performances on the pre-test. It would appear that the slower the individual initially the more likely he benefited from isometric or speed exercises.

Arm Endurance (Table 6, Page 75, and Figure 35, Page 82). With F_1 well below the level of confidence, the regression lines for arm endurance can be assumed to have a common slope. A check of co-linearity reveals differences significant at the .05 level between isometric and speed and between isotonic and isometric methods. In fact, the F-ratios of 6.04 for the latter approaches the .01 level (F = 6.96). These findings indicate that the speed exercises were slightly better than the isometric program and the isotonic method was decidedly superior to the isometric exercises, particularly for those having considerable endurance at the outset.

Leg Endurance (Table 6, Page 75, and Figure 36, Page 83). There is a very significant difference among the slopes of the regression lines for leg endurance and all lines intersect within the range of interest. The high values for F_3 and F_4 indicate that the differences among slopes are between Groups I and III and between II and III. A further check reveals that the lines for Groups I and II and co-linear (F_5). The common line for these two groups intersects that for Group III at 53.8, which is well below the mean of the pre-test. Thus it seems that speed exercises were best in developing leg endurance for a majority of the subjects and were decidedly more effective for those with high pre-test scores.

Arm Power (Table 7, Page 76, and Figure 37, Page 84). The regression lines for arm power are considered parallel and co-linear with both F_1 and F_8 well below the level of confidence. One may conclude therefore that there was no difference in treatment effects for this attribute.

Leg Power (Table 7, Page 76, and Figure 38, Page 85). The regression lines for leg power appear to have a common slope; however, F_1 approaches significance at the .05 level. Furthermore, the lines intersect within the range of interest. The low value for F_8 indicates co-linearity, suggesting no difference in treatment effects. Nevertheless, one might conclude that the isometric program was best for subjects who were extremely low in strength, while the strongest individuals improved most with isotonic or speed exercises.

Discussion

In discussing the findings of this study, an attempt will be made to make comparisons with the results obtained from similar investigations. In most of the related research, attention was focused on comparing isometric contraction with the traditional isotonic program of moving heavy loads at a moderate rate of speed. The load and rate were varied in a few studies, but none included the rapid contraction against resistance as used in the speed exercises of this program.

Strength. The findings of the study relative to strength seemingly are similar to those of other investigations. In most instances where the isotonic and isometric methods have been compared, no significant differences were found and strength was improved by both programs. How-

Table I

Means and Standard Deviations for the Isotonic Group

Variable	Unit of Measure	Means		Standard Deviations	
		Pre	Post	Pre	Post
Arm strength	pounds	56.0	63.6	21.0	20.7
Arm speed	seconds	.299	.296	.034	.031
Arm power	inches	121.9	124.8	29.9	31.3
Arm endurance	repetitions	70.3	79.3	33.8	57.0
Leg strength	pounds	435.9	530.0	45.3	38.0
Leg speed	seconds	.290	.274	.033	.039
Leg power	inches	20.63	22.06	2.64	2.96
Leg endurance	repetitions	81.7	82.5	99.6	86.8
Starting speed	seconds	.899	.930	.075	.062

Table 2

Means and Standard Deviations for the Isometric Group

Variable	Unit of Measure	Means Pre	Means Post	Standard Deviations Pre	Standard Deviations Post
Arm strength	pounds	53.3	58.0	21.0	18.7
Arm speed	seconds	.301	.290	.024	.033
Arm power	inches	117.4	114.2	27.8	22.9
Arm endurance	repetitions	81.6	61.6	39.0	23.7
Leg strength	pounds	397.7	485.0	53.7	51.3
Leg speed	seconds	.290	.271	.028	.021
Leg power	inches	20.79	21.61	2.59	2.18
Leg endurance	repetitions	95.1	88.7	74.5	86.3
Starting speed	seconds	.905	.905	.078	.055

Table 3

Means and Standard Deviations for the Speed Group

Variable	Unit of Measure	Means		Standard Deviations	
		Pre	Post	Pre	Post
Arm strength	pounds	55.6	59.0	19.7	20.7
Arm speed	seconds	.288	.287	.022	.024
Arm power	inches	129.2	119.4	31.4	31.5
Arm endurance	repetitions	69.4	75.1	31.6	39.4
Leg strength	pounds	427.0	510.0	56.7	36.7
Leg speed	seconds	.277	.266	.032	.023
Leg power	inches	21.37	22.16	2.64	2.94
Leg endurance	repetitions	81.6	105.1	52.1	100.5
Starting speed	seconds	.885	.903	.064	.057

Table 4

F-Ratios for Strength

	F-Ratio Sub-script	df_1	df_2	RSQ_r	RSQ_f	F-Ratio	P
Arm strength:							
Slope: All groups	1	2	87	.448	.471	1.89	NS
Co-linearity: All groups	8	2	89	.411	.448	2.67	NS
Leg strength:							
Slope: All groups	1	2	87	.349	.399	3.59	.05
Slope: Isotonic-Isometric	2	1	87	.399	.399	.00	NS
Slope: Isotonic-Speed	3	1	87	.364	.399	5.02	.05
Slope: Isometric-Speed	4	1	87	.362	.399	5.29	.05
Co-linearity: Isotonic-Isometric	5	1	88	.397	.399	.25	NS

Table 5

F-Ratios for Speed

	F-Ratio Sub-script	df_1	df_2	RSQ_r	RSQ_f	F-Ratio	P
Arm speed:							
Slope: All groups	1	2	87	.370	.379	.63	NS
Co-linearity: All groups	8	2	89	.358	.370	.70	NS
Leg speed:							
Slope: All groups	1	2	87	.192	.227	1.94	NS
Co-linearity: All groups	8	2	89	.189	.192	.17	NS
Starting speed:							
Slope: All groups	1	2	87	.352	.357	.28	NS
Co-linearity: All groups	8	2	89	.313	.352	2.32	NS

Table 6

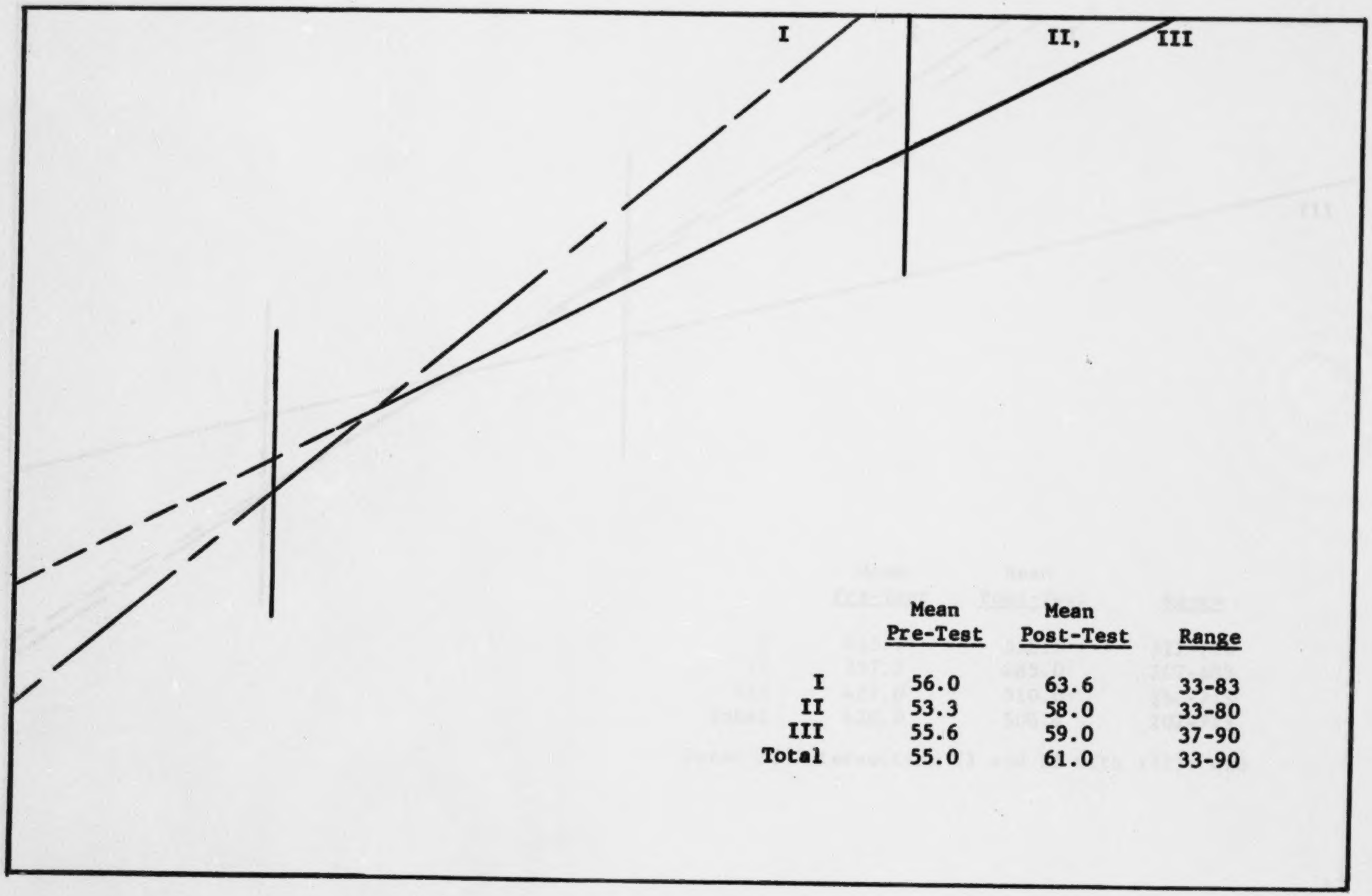
F-Ratios for Endurance

	F-Ratio Sub-script	df_1	df_2	RSQ_r	RSQ_f	F-Ratio	P
Arm endurance:							
Slope: All groups	1	2	87	.238	.264	1.57	NS
Co-linearity: All groups	8	2	89	.179	.238	3.43	.05
Co-linearity: Isotonic-Isometric	9	1	89	.186	.238	6.04	.05
Co-linearity: Isotonic-Speed	10	1	89	.237	.238	.12	NS
Co-linearity: Isometric-Speed	11	1	89	.201	.238	4.30	.05
Leg endurance:							
Slope: All groups	1	2	87	.553	.639	10.36	.01
Slope: Isotonic-Isometric	2	1	87	.626	.639	3.07	NS
Slope: Isotonic-Speed	3	1	87	.587	.639	12.60	.01
Slope: Isometric-Speed	4	1	87	.554	.639	20.58	.01
Co-linearity: Isotonic-Isometric	5	1	88	.626	.626	.00	NS

Table 7

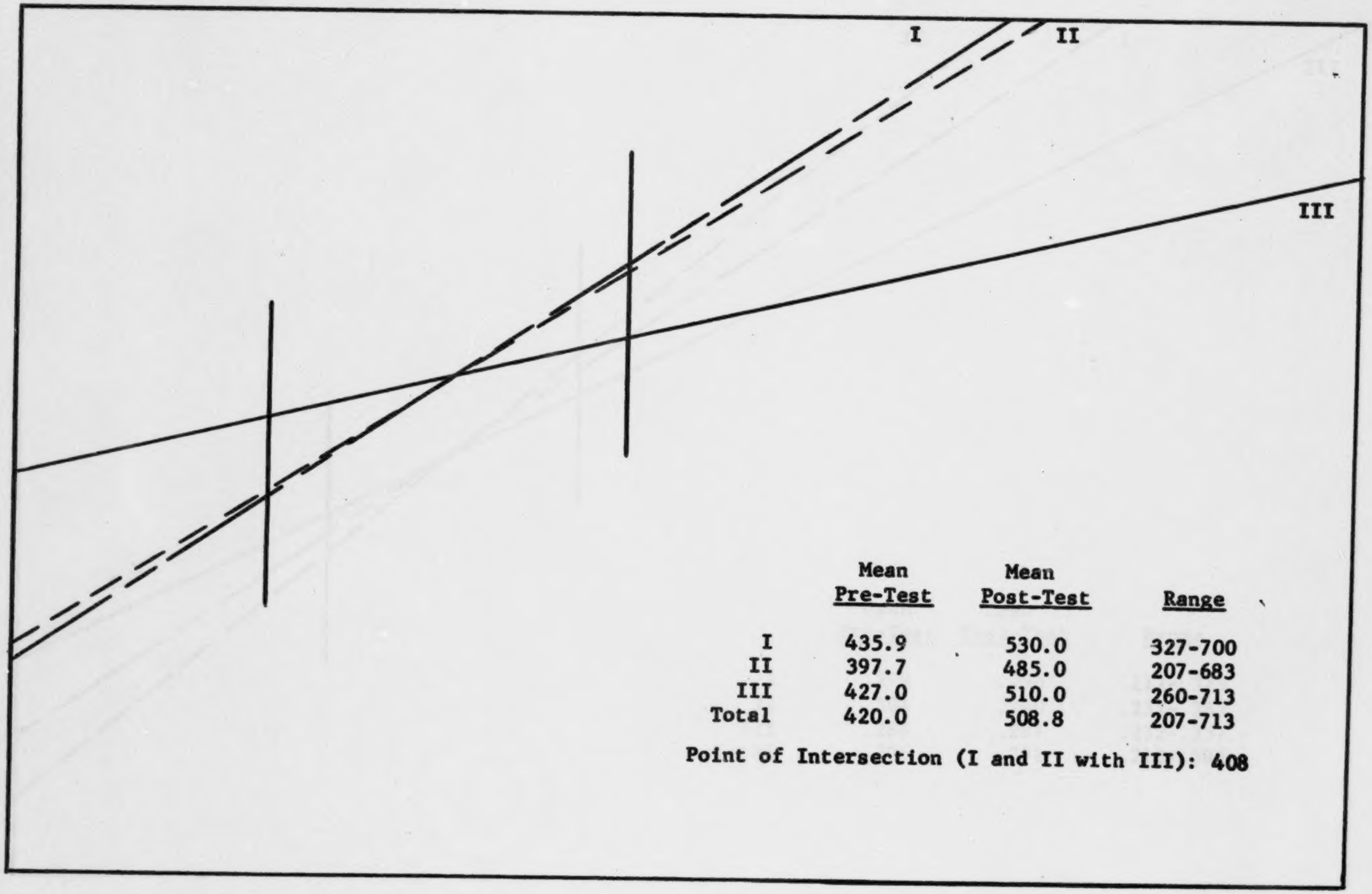
F-Ratios for Power

	F-Ratio Sub-script	df_1	df_2	RSQ_r	RSQ_f	F-Ratio	P
Arm power:							
Slope: All groups	1	2	87	.308	.329	1.36	NS
Co-linearity: All groups	8	2	89	.288	.308	1.28	NS
Leg power:							
Slope: All groups	1	2	87	.653	.675	2.98	NS
Co-linearity: All groups	8	2	89	.644	.653	1.15	NS



	Mean Pre-Test	Mean Post-Test	Range
I	56.0	63.6	33-83
II	53.3	58.0	33-80
III	55.6	59.0	37-90
Total	55.0	61.0	33-90

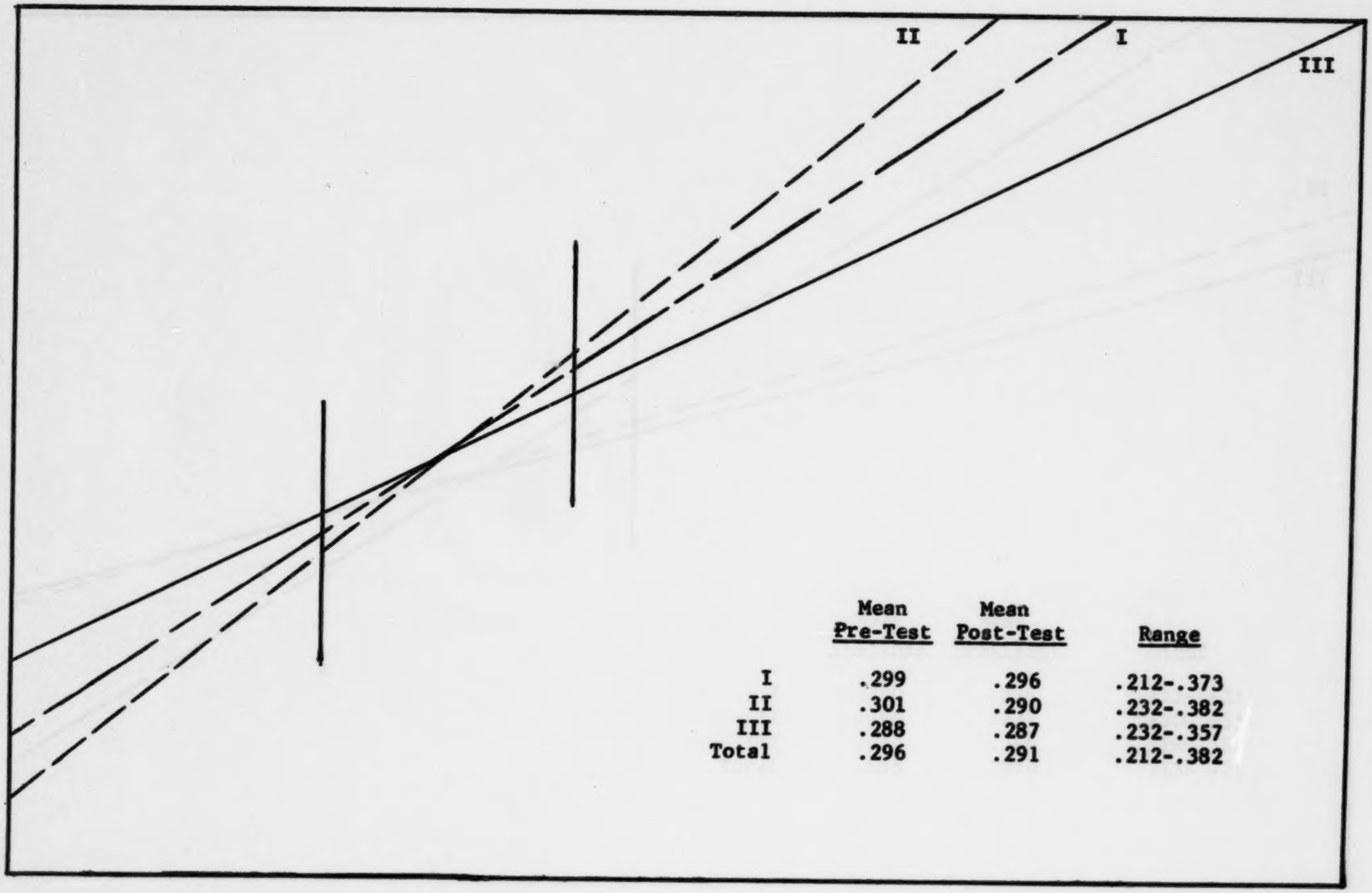
Figure 30. Regression Lines for Arm Strength



	Mean Pre-Test	Mean Post-Test	Range
I	435.9	530.0	327-700
II	397.7	485.0	207-683
III	427.0	510.0	260-713
Total	420.0	508.8	207-713

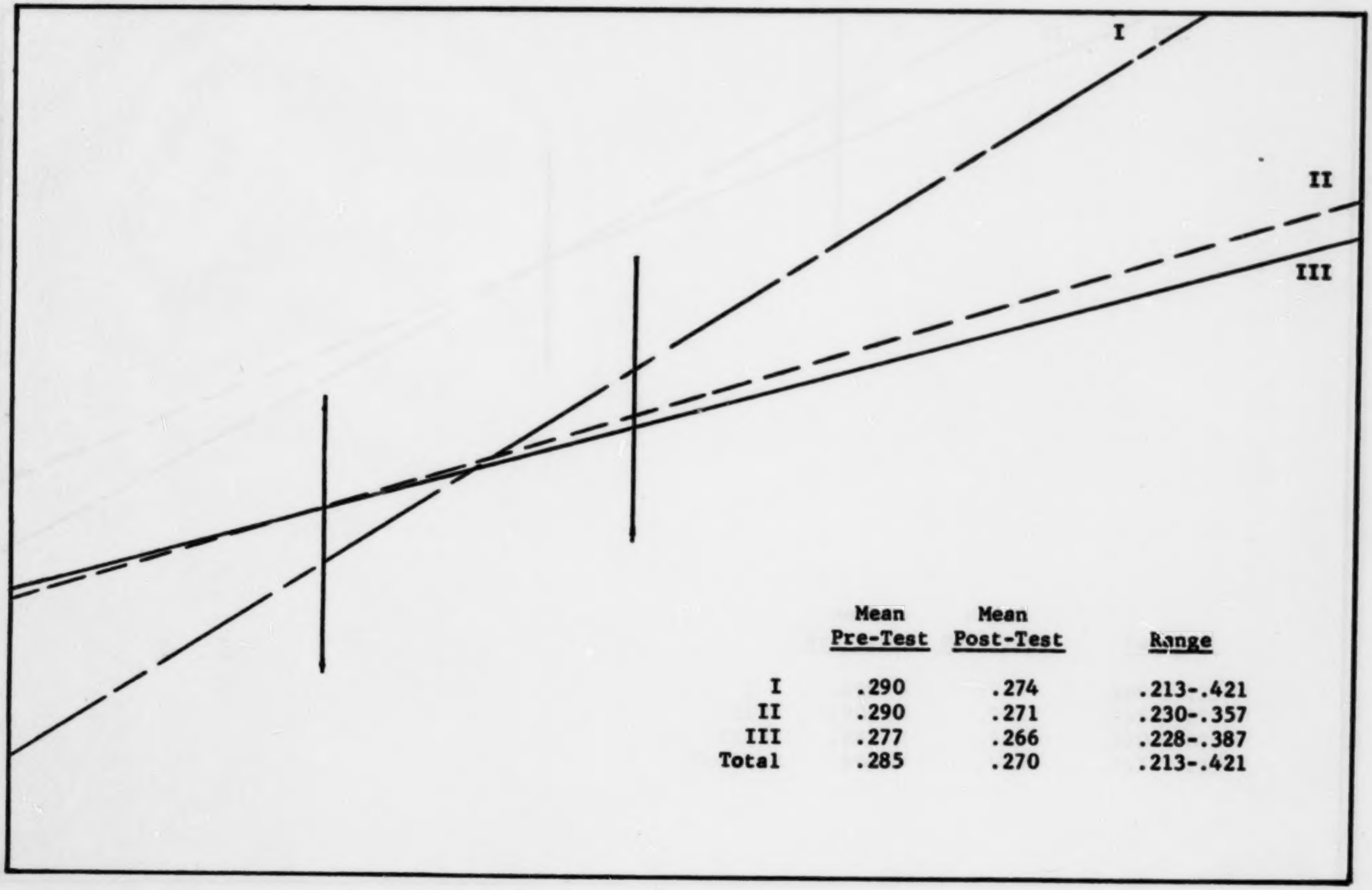
Point of Intersection (I and II with III): 408

Figure 31. Regression Lines for Leg Strength



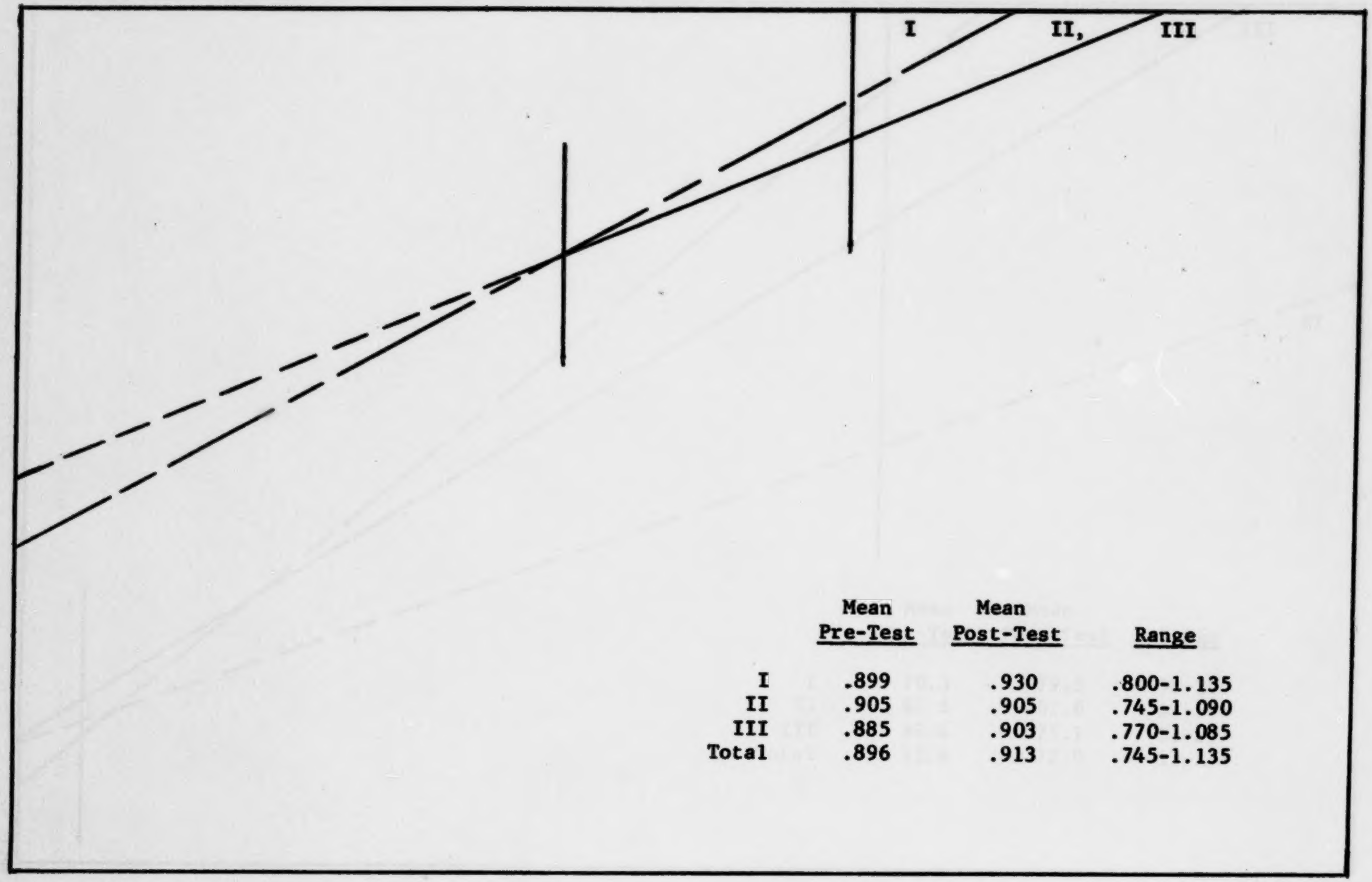
	Mean Pre-Test	Mean Post-Test	Range
I	.299	.296	.212-.373
II	.301	.290	.232-.382
III	.288	.287	.232-.357
Total	.296	.291	.212-.382

Figure 32. Regression Lines for Arm Speed



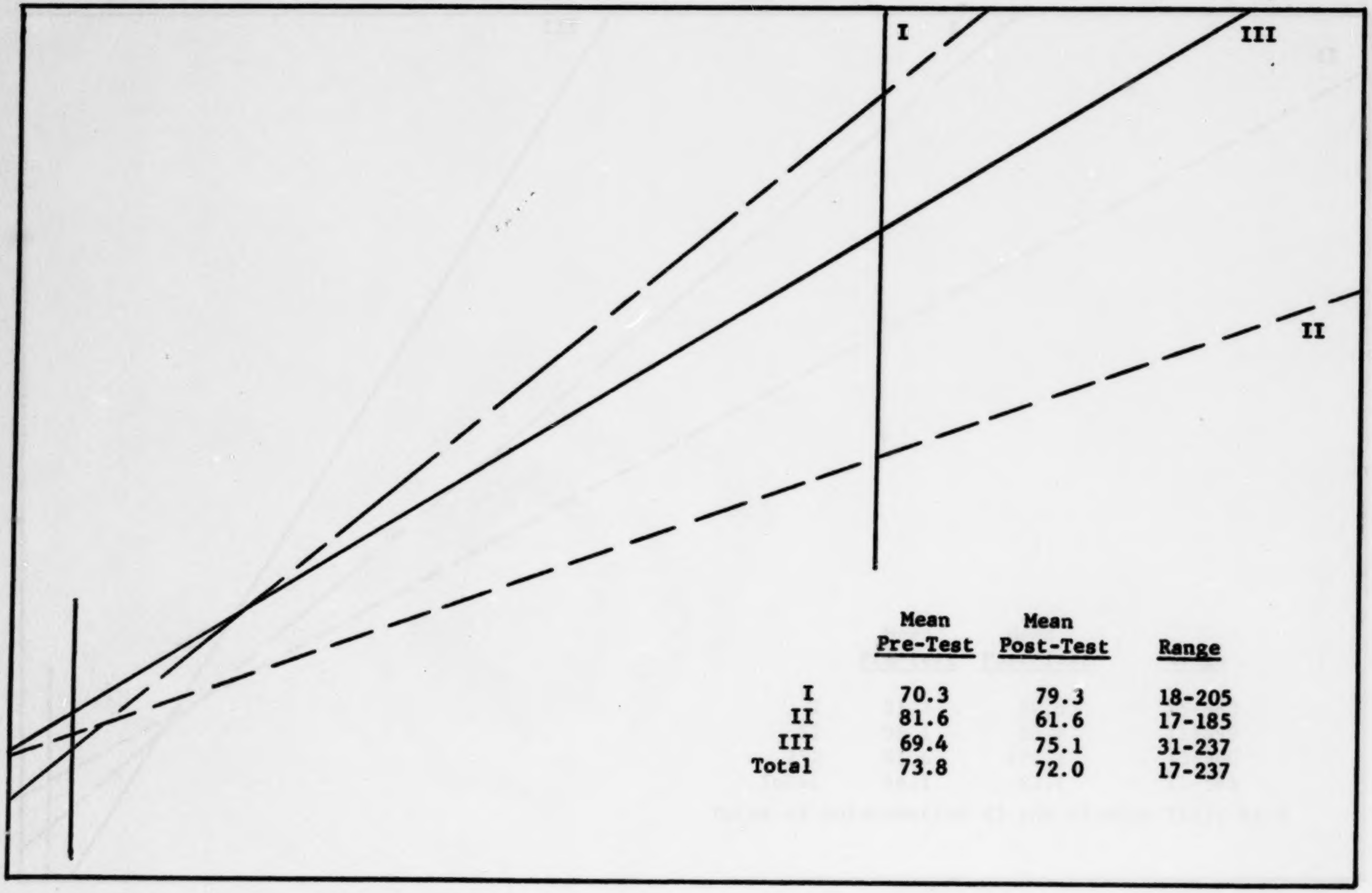
	Mean Pre-Test	Mean Post-Test	Range
I	.290	.274	.213-.421
II	.290	.271	.230-.357
III	.277	.266	.228-.387
Total	.285	.270	.213-.421

Figure 33. Regression Lines for Leg Speed



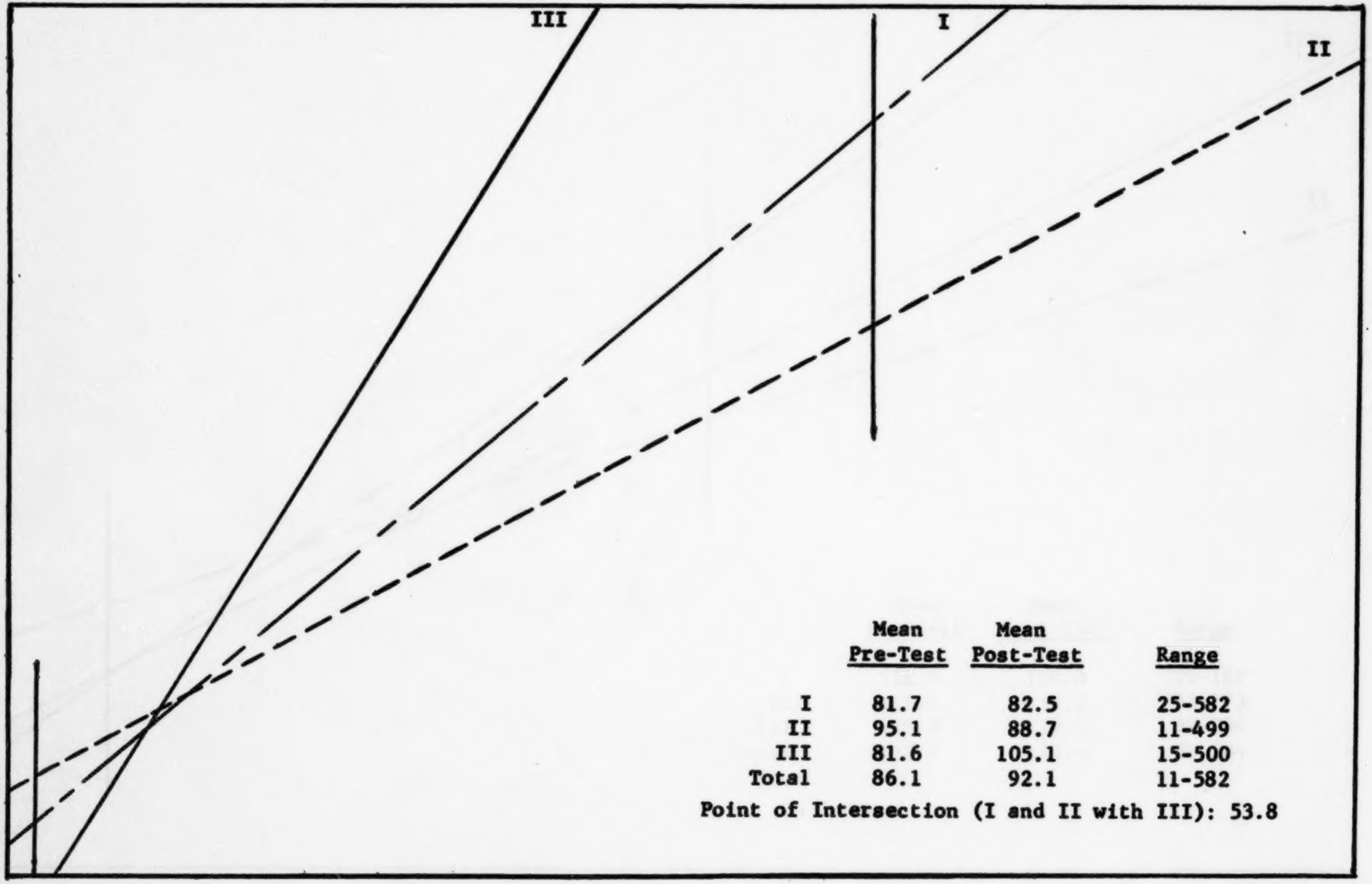
	Mean Pre-Test	Mean Post-Test	Range
I	.899	.930	.800-1.135
II	.905	.905	.745-1.090
III	.885	.903	.770-1.085
Total	.896	.913	.745-1.135

Figure 34. Regression Lines for Starting Speed



	Mean Pre-Test	Mean Post-Test	Range
I	70.3	79.3	18-205
II	81.6	61.6	17-185
III	69.4	75.1	31-237
Total	73.8	72.0	17-237

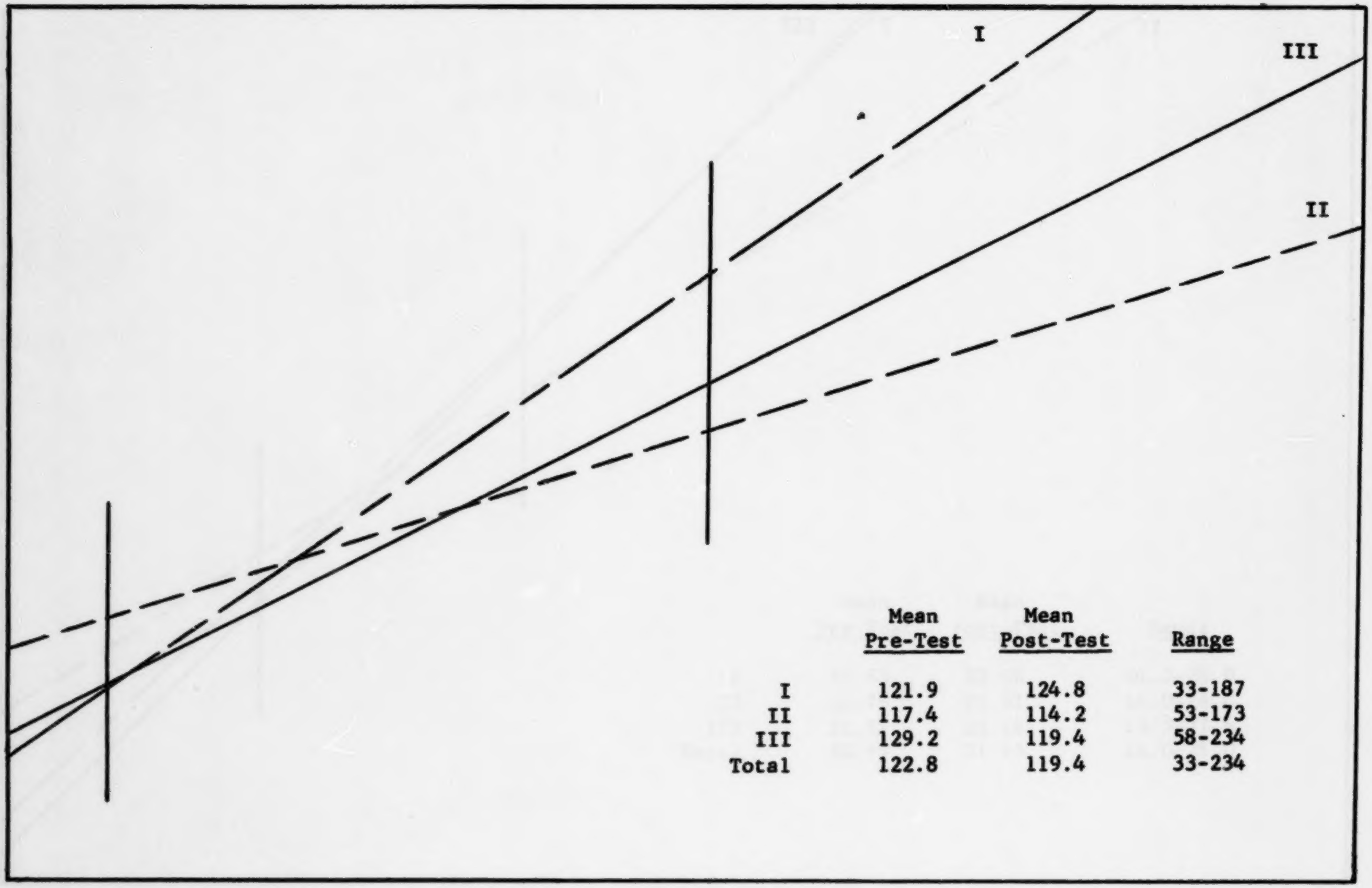
Figure 35. Regression Lines for Arm Endurance



	Mean Pre-Test	Mean Post-Test	Range
I	81.7	82.5	25-582
II	95.1	88.7	11-499
III	81.6	105.1	15-500
Total	86.1	92.1	11-582

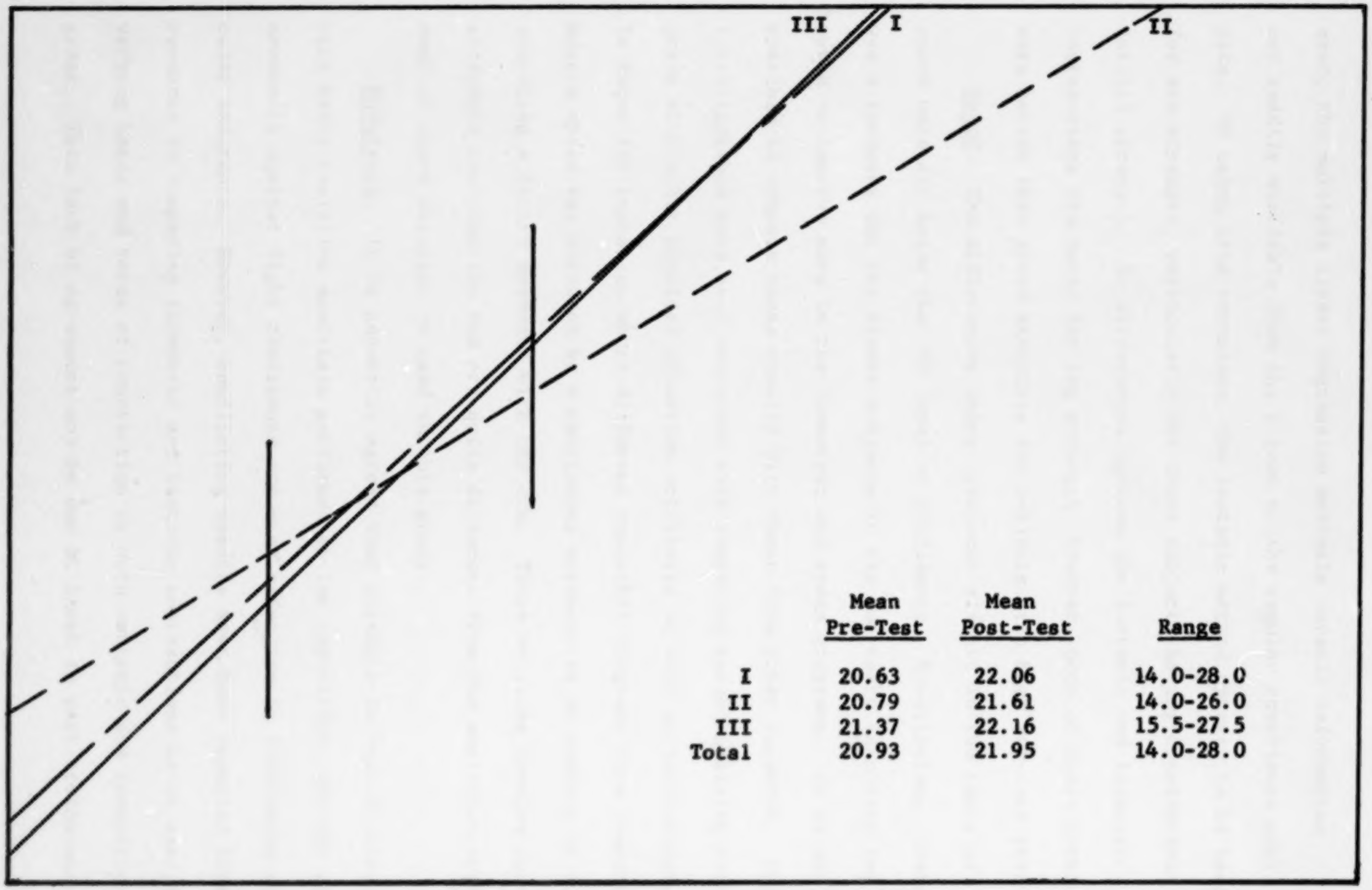
Point of Intersection (I and II with III): 53.8

Figure 36. Regression Lines for Leg Endurance



	Mean Pre-Test	Mean Post-Test	Range
I	121.9	124.8	33-187
II	117.4	114.2	53-173
III	129.2	119.4	58-234
Total	122.8	119.4	33-234

Figure 37. Regression Lines for Arm Power



	Mean Pre-Test	Mean Post-Test	Range
I	20.63	22.06	14.0-28.0
II	20.79	21.61	14.0-26.0
III	21.37	22.16	15.5-27.5
Total	20.93	21.95	14.0-28.0

Figure 38. Regression Lines for Leg Power

ever, the multiple linear regression analysis reveals information not readily available from the t test or the regular covariance analysis. In using this technique, the isotonic method appears to be best for arm strength, particularly for those subjects having considerable initial strength. No differences between the isotonic and isometric contractions are noted for leg strength; however, both of these methods were better than speed exercises for subjects with high pre-test scores.

Speed. The differences among treatment effects in the tests of speed were all below the .05 level of confidence. Nevertheless, there was a tendency for the slower subjects in the two tests involving leg speed to improve more in the isometric and speed programs. It is not possible to compare these results with those from other research. Most investigations have been concerned with comparing weight training programs with other physical education activities or with no instruction. In those few instances where different resistive programs were compared, muscle speed was measured by a continuous movement as in running or in executing a rotary movement with the arm. These measures involve considerable coordination and are quite different from the explosive movement of short duration as used in this study.

Endurance. It is generally agreed that strength is best developed with heavy resistive exercises performed at low repetition, whereas rapid movements against light resistance are most effective in developing muscular endurance. However, conflicting results have been reported from research in comparing isometric and isotonic contractions or in analyzing varying loads and rates of contraction in both isotonic and isometric programs. This lack of agreement may be due at least in part to the use of different procedures in measuring endurance. In many studies a constant load was used for all subjects irrespective of the strength. In other investigations the resistance was based on the strength of the muscle, i.e. the stronger the subject, the greater the load. The latter procedure was followed in this study and is considered by such authorities as Clarke and Hellebrandt to be the most valid measure of endurance.

It is well known that as the muscle increases in strength it can move the same load longer and more readily. Thus it would appear that strength and endurance are closely related. As previously noted, Steinhaus has stated that the ability of the muscle to contract repeatedly is related to its strength. While this contention may hold in contractions against a constant load, it does not appear to be true for repeated contractions against a resistance that is related to the strength of the muscle. In this study correlations of -.33 and -.31 were obtained between strength and endurance for tests of the arm and leg respectively. Furthermore, the isometric program produced considerable improvement in strength, whereas there was a decrease in scores for the endurance tests. On the other hand the isotonic and speed groups, particularly those subjects with high pre-test scores, exhibited substantial improvement in endurance.

A question might well be raised about the apparent contradiction of these latter findings in that the isotonic program was most effective for arm endurance while speed exercises produced the most improvement for endurance of the leg. It should be remembered that the speed movements are isotonic in nature so that the differences between these two programs is in the load and rate of contraction. On the basis of these findings, it would seem that isotonic movements are best for developing the endurance of the muscle in contracting against a heavy resistance when that resistance is related to the amount of strength. The problem then becomes one of determining how much resistance and how rapid a rate of contraction to use in the exercise program.

Power. Numerous investigators have reported that weight training produced significant increases in power; however, only a few attempted to compare the effectiveness of different types of programs. Although not conclusive, the results from these comparisons seem to indicate that improvement in power is related to an increase in strength irrespective of how the latter is developed. The findings from the test of leg power in this study substantiate this hypothesis. However, it appears that the effectiveness of methods may vary according to the initial status of subjects. The isotonic and isometric methods proved best in developing strength of subjects having high pre-test scores while isotonic and speed exercises were most effective for those with low scores. It is possible therefore that power is best developed by improving strength through movement. This would seem logical when one considers that power is defined as the rate of doing work.

Adaptation of Methods

Any recommendation for modifying existing programs so as to make them more applicable to a practical situation must necesarily be based primarily on a subjective analysis. Nevertheless, in selecting exercises for various muscle groups, one should take note of the objective data obtained from this and other investigations. Certainly no program should include an exercise that does not produce results. Other factors to be considered are cost of facilities and equipment, economy of time, ease of administration, and motivation of participants.

In comparing the exercise methods on the basis of cost, one must conclude that an isotonic program would be least desirable. A complete set of bar bell and weights would cost approximately $25.00 as compared with $3.00 for an isometric strap. The speed exercises actually require no equipment although two or three subjects in this study used weighted vests. At least twenty sets of bar bells and weights or twenty isometric straps should be provided for a normal class of forty students. Thus the cost for the isotonic program would be substantially more than for the other methods.

An attempt was made to control the time factor in this study so that the duration of the exercises was approximately the same for all subjects. Nevertheless, the programs differ by their very nature. The isometric program logically should take less time since only a single contraction of 6 seconds is required for each exercise. Furthermore, considerably more time is needed in the isotonic program to prepare for the exercise. Weights must be selected and adjusted and the subject must make certain that he is in the correct position to execute the movement.

Since it is individualized, the isotonic program is much more difficult to administer than are either the isometric or speed exercises. The weights for each subject are selected in terms of his strength, and these are changed as strength is improved. This necessitates some sort of record system to be maintained either by the instructor or students. On the other hand, the isometric and speed exercises can best be administered by having at least half of the class execute the movements together in response to a command from the instructor.

Although some might contend that individuals are motivated more when performing a task within a specified time as in the speed exercises, there was no indication of differences in motivation among the subjects in this study. Quite often the newness or uniqueness of the technique causes individuals to pursue an exercise program more religiously than otherwise. More often, however, the motivating factor is the desire to improve and the method is merely a means in doing so.

On the basis of the findings of this study and in view of the above considerations, it would seem that a combination of isometric and speed exercises would be best for a practical classroom situation. Insofar as possible, both types of contractions should be used for each muscle group since the objective is to develop speed, power, and endurance as well as strength. This might be done by combining isometric and speed movements within each class period. It can possibly best be done by alternating the exercise regime so that students perform speed exercises one day and then on the next day execute the isometric contractions.

IV. CONCLUSIONS AND IMPLICATIONS

This study has been concerned with a comparison of isotonic, isometric, and speed exercise programs as a means of developing the strength, endurance, speed, and power of the muscles. Data from a pre-test and post-test were analyzed through use of the multiple linear regression technique for covariance analysis. The results from this analysis proved the basis for the following conclusions:

1. No single method is adequate in achieving maximum development of all four attributes of strength, endurance, speed, and power of the muscles.

2. The extent to which a particular method is effective may well depend on the initial status of the individual on the attribute in question. One resistive method may be most effective for persons low in the attribute while another may be best for those with considerable amount at the outset.

3. While strength may be developed with any one of the three resistive programs, the isotonic and isometric methods appear to be best for persons who are strong initially.

4. Resistive exercises do not appreciably affect the speed of the muscle in moving a segment of the body such as the arm or leg.

5. There is a slight negative relationship between the strength and endurance of the muscle, when in measuring endurance the load is related to strength.

6. Muscle endurance as measured in this study can best be devel-

oped by repeated contractions of the muscle, performed as rapidly as possible against a reasonably heavy load.

7. Isotonic and speed movements are probably more effective than isometric contractions in improving explosive power for those individuals having considerable quantity of this attribute.

This study has implications both for application of the resistive exercise methods to a practical situation and for further research as to the effects of these methods in developing the strength, endurance, speed, and power of muscles. These implications are based on experience in using the methods in the research program as well as from the analysis of the data.

Persons responsible for planning and conducting a conditioning program should select exercise methods that best develop the individual according to his status on the attributes in question. This implies further that as progress is made, methods should be changed in order to achieve maximum results. A conditioning program designed to develop several attributes should include a combination of methods. Two or more methods might be integrated within a single exercise session or they could possibly be alternated from day to day.

In planning the exercise program, consideration should also be given to such factors as cost of equipment, economy of time, and ease of administration. It would be difficult to justify using a method that is rated low on such factors unless decidedly better results can be achieved.

As revealed through a review of the literature, numerous investigators have studied the effects of weight training and other resistive exercise programs. Much has been learned from this research, but there still remains many problems to be solved. Several questions raised in this study have definite implications for future research. The following include possible suggestions for such research:

1. Attention should be directed to studying the effects of exercise programs according to the initial status of subjects. While pretest scores have been considered in covariance analysis, little or no attention has been given to determining differences in treatment effects for persons with low initial status as compared with those possessing a considerable amount of the attribute in question.

2. In studying the effect of resistive exercise programs on the speed of movement, an attempt should be made to control the load against which the muscle contracts. The loads in previous investigations have varied from a negligible amount, as in moving the arm, to the weight of the body itself.

3. An analysis should be made of methods of measuring muscle endurance. The literature contains conflicting opinions as to the nature of endurance, and present methods of measurement yield contradictory results.

REFERENCES

1. Asa, M. M., *Effect of Isotonic and Isometric Exercise upon the Strength of Muscle*. Unpublished Doctor's Dissertation, Springfield College, 1958.

2. Asmussen, E., "Positive and Negative Muscular Work," *Acta Physiologica Scandinavica*, 28:364-382, 1952.

3. Asmussen, E., "Training of Muscular Strength by Static and Dynamic Activity," *Kongressen Voredrog*, *Linqiaden*, Stockholm, 11:22-23, 1949.

4. Baer, Adrian D., Jerome W. Gersten, Barbara M. Robertson, and Harold Dinken, "Effect of Various Exercise Programs on Isometric Tension, Endurance, and Reaction Time in the Human," *Archives of Physical Medicine and Rehabilitation*, 36:495-502, August, 1955.

5. Berger, Richard A., "Comparison of Static and Dynamic Strength Increases," *Research Quarterly*, 33:329-333, October, 1962.

6. Berger, Richard A., "Optimum Repetitions for the Development of Strength," *Research Quarterly*, 33:334-338, October, 1962.

7. Bottenberg, Robert A., and Joe H. Ward, Jr., *Applied Multiple Linear Regression*, Technical Documentary Report PRL-TDR, Lackland Air Force Base, Texas: 6570th Personnel Research Laboratory, March, 1963.

8. Burnham, Stan, and Lynn W. McCraw, *Directions for Using Frank's Iso-Strap*, Lubbock, Texas: Frank's Products Inc., 1962.

9. Burnham, Stan, "Overload Training for Athletes," Research Report to Intercollegiate Athletic Section of College Physical Education Association. 66th Annual Meeting, December 26-29, 1962. Mimeographed.

10. Capen, Edward K., "A Study of Four Programs of Heavy Resistance Exercises for Development of Muscular Strength," *Research Quarterly*, 27:132-142, May, 1956.

11. Capen, Edward K., "The Effect of Systematic Weight Training on Power, Strength, and Endurance," *Research Quarterly*, 21:83-93, May, 1950.

12. Chui, Edward, "The Effect of Systematic Weight Training on Athletic Power," *Research Quarterly*, 21:188-194, October, 1950.

13. Clarke, David H., "Energy Cost of Isometric Exercise," *Research Quarterly*, 31:3-6, March, 1960.

14. Clarke, David H., and Edward L. Herman, "Objective Determination of Resistance Load for Ten Repetitions Maximum for Quadriceps Development," Research Quarterly, 26:385-390, December, 1955.

15. Clarke, H. Harrison, Cable-Tension Strength Tests. Springfield, Mass.:Stuart E. Murphy, 1953.

16. Clarke, H. Harrison, "Precision of Elbow Flexion Ergography Under Varying Degrees of Muscular Fatigue," Archives of Physical Medicine, 33:279-288, May, 1952.

17. Clarke, H. Harrison, Clayton T. Shay, and Donald K. Mathews, "Strength and Endurance (Conditioning) Effects of Exhaustive Exercise of the Elbow Flexor Muscles," Journal of the Association for Physical and Mental Rehabilitation, 8:184-188, November-December, 1954.

18. Counsilman, James E., "Does Weight Training Belong in the Program?" Journal of Health, Physical Education, Recreation, 26:17-18, 20, January, 1955.

19. Crakes, James G., An Analysis of Some Aspects of an Exercise and Training Program Developed by Hettinger and Mueller. Unpublished Master's Thesis, University of Oregon, 1957.

20. Darcus, H. D., and Nancy Salter, "The Effect of Repeated Muscular Exertion on Muscle Strength," Journal of Physiology, 129:325-336, August, 1955.

21. DeLorme, T. L., B. G. Ferris, and J. Roswell Gallagher, "Effects of Progressive Resistance Exercise on Muscle Contraction Time, Archives of Physical Medicine, 33:86-92, February, 1952.

22. DeLorme, Thomas L., and Arthur L. Watkins, Progressive Resistance Exercise Technic and Medical Application. New York: Appleton-Century-Crofts, Inc., 1951.

23. DeLorme, Thomas L., "Restoration of Muscle Power by Heavy Resistance Exercise," Journal of Bone and Joint Surgery, 27:645-667, October, 1945.

24. Dennison, J. D., M. L. Howell, and W. R. Morford, "Effect of Isometric and Isotonic Exercise Programs upon Muscular Endurance," Research Quarterly, 32:348-352, October, 1961.

25. Eckstrom, Conrad T., A Study of the Effect of Increasing Upper Extremity and Shoulder Girdle Strength in the Velocity of Throwing a Baseball, Unpublished Master of Education Thesis, Iowa University, Iowa City, Iowa, 1955.

26. Ferguson, Albert B., "Exercises for Athletes," Journal of Bone and Joint Surgery, 44-A:1177-1182, September, 1962.

27. Garth, Richard L., A Study of the Effect of Weight Training On the Jumping Ability of Basketball Players, Unpublished Master of Arts Thesis. Iowa University, Iowa City, Iowa, August, 1953.

28. Hellebrandt, F. A., and Sara Jane Houtz, "Mechanism of Muscle Training in Man: Experimental Demonstration of the Overload Principle," Physical Therapy Review, 36:371-383, June, 1956.

29. Hellebrandt, F.A., "Recent Advances in Methods of Hastening Convalescence Through Exercise," Southern Medical Journal, 39:398-401, May, 1946.

30. Henry, Franklin M., and J. D. Whitely, "Relationship Between Individual Differences in Strength, Speed, and Mass in an Arm Movement," Research Quarterly, 31:24-33, March, 1960.

31. Hettinger, Thomas, and E.A. Muller, "Muskelleistung and Muskelltraining," Arbeitsphysiologie, 15:111-126, October, 1953.

32. Howell, Maxwell L., Ray Kimoto, and W. R. Morford, "Effect of Isometric and Isotonic Exercise Programs upon Muscular Endurance," Research Quarterly, 33:536-540, December, 1962.

33. Kroll, Walter, "Reliability of Selected Measures of Human Strength," Research Quarterly, 33:410-417, October, 1962.

34. Kruse, R. D., and K. Mathews, "Bilateral Effects of Unilateral Exercise: Experimental Study Based on 120 Subjects," Archives of Physical Medicine, 39:371-376, June, 1958.

35. Lawther, John D., "The Pennsylvania State University Studies on Strength Decrement, Maintenance, and Related Aspects," 61st Annual Proceedings, College Physical Education Association, 1958, pp. 142-149.

36. Liberson, W. T., and M. Maxim Asa, "Further Studies of Brief Isometric Exercises," Archives of Physical Medicine and Rehabilitation, 40:330-336, August, 1959.

37. McCraw, Lynn W., "Conditioning by the Use of Speed Exercises," Report to Research Section of American Association for Health, Physical Education, and Recreation. National Convention, April 6-10, 1962. Mimeographed.

38. Masley, John W., Ara Hairabedian, and Donald N. Donaldson, "Weight Training in Relation to Strength, Speed, and Coordination," Research Quarterly, 24:308-315, October, 1953.

39. Massey, Benjamin H., and Norman L. Chaudet, "Effects of Systematic, Heavy Resistive Exercise on Range of Joint Movement in Young Male Adults," Research Quarterly, 27:41-51, March, 1956.

40. Massey, Benjamin H., Harold W. Freeman, Frank R. Manson, and Janet A. Wessel, The Kinesiology of Weight Lifting. Dubuque, Iowa: Wm. C. Brown Company Publishers, 1959.

41. Mathews, D. K., T. S. Clayton, F. Godin and R. Hogdon, "Cross Effect of Training on Strength and Endurance," Research Quarterly, 27:206-212, May, 1956.

42. Mathews, Donald K., and Robert Kruse, "Effects of Isometric and Isotonic Exercises on Elbow Flexor Muscle Groups," Research Quarterly, 28:26-37, March, 1957.

43. Meadow, Paul Eugene, The Effect of Isotonic and Isometric Muscle Contraction Training on Speed, Force, and Strength, Unpublished Doctoral Dissertation, University of Illinois, Urbana, 1959.

44. Muller, E. A., "Training Muscle Strength," Ergonomics, 2:216-222, February, 1959.

45. Muller, Erich A., "The Regulation of Muscular Strength," Journal of the Association for Physical and Mental Rehabilitation, 11:41-47, March-April, 1957.

46. Petersen, Flemming Bonde, "Muscle Training by Static, Concentric and Eccentric Contraction," Acta Physiologica Scandinavica, 48:406-416, 1960.

47. Pierson, William R., and Eugene R. O'Connell, "Age, Height, Weight, and Grip Strength," Research Quarterly, 33:439-443, October, 1962.

48. Rasch, Philip J., and Laurence E. Morehouse, "Effect of Static and Dynamic Exercise on Muscular Strength and Hypertrophy," Journal of Applied Physiology, 11:29-34, July, 1957.

49. Rasch, Philip J., "Relationship Between Maximum Isometric Tension and Maximum Isotonic Elbow Flexion, Research Quarterly, 28:85, March, 1957.

50. Rasch, Philip J., "Relationship of Arm Strength, Weight and Length to Speed of Movement," Research Quarterly, 25:328-332, October, 1954.

51. Rasch, Philip J., and R. V. Freeman, "The Physiology of Progressive Resistance Exercise," Journal of the Association for Physical and Mental Rehabilitation, 8:35-41, March-April, 1954.

52. Rarick, G. Lawrence, and Gene L. Larsen, "Observations on Frequency and Intensity of Isometric Muscular Effort in Developing Static Strength in Post Pubescent Males," Research Quarterly, 29:333-341, October, 1958.

53. Rodgers, Donald P., *The Development of Strength by Means of Static and Concentric Muscle Contractions*. Unpublished Master of Arts Thesis, University of Iowa, Iowa City, Iowa, June, 1956.

54. Rose, Donald L., Stanley F. Radzyminski, and Ralph R. Beatty, "Effect of Brief Maximal Exercise on the Strength of the Quadriceps Femoris," *Archives of Physical Medicine and Rehabilitation*, 38:157-164, March, 1957.

55. Royce, Joseph, "Isometric Fatigue Curves in Human Muscle with Normal and Occluded Circulation," *Research Quarterly*, 29:204-212, May, 1958.

56. Salter, Nancy, "The Effects on Muscle Strength of Maximum Isometric and Isotonic Contractions at Different Repetition Rates," *Journal of Physiology*, 130:109-113, October, 1955.

57. Smith, Leon E., "Individual Differences in Strength, Reaction Latency, Mass and Length of Limbs, and their Relation to Maximum Speed of Movement, *Research Quarterly*, 32:208-220, May, 1961.

58. Steinhaus, Arthur H., "Strength from Morpurgo to Muller - A Half Century of Research," *Journal of the Association for Physical and Mental Rehabilitation*, 9:147-150, September-October, 1955.

59. Steinhaus, Arthur H., *Toward an Understanding of Health and Physical Education*. Dubuque, Iowa: Wm. C. Brown Company Publishers, 1963.

60. Texas Education Agency, *Suggestions for Planning the Secondary School Physical Education Program*, Bulletin 625. Austin, Texas: Texas Education Agency, March, 1963.

61. Wallace, Joseph, "The Development of Muscular Strength and Muscular Endurance Through Isotonic and Isometric Exercise," *New Zealand Journal of Physical Education*, 14:3-9, April, 1958.

62. Ward, Joe H. Jr., "Multiple Linear Regression Models," *Computer Applications in the Behavioral Sciences*, Edited by Harold Borko. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1962, pp. 204-237.

63. Wickstrom, Ralph L., "An Observation on Isometric Contraction as a Training Technique," *Journal of the Association for Physical and Mental Rehabilitation*, 12:162, 166, September-October,1958.

64. Wilkie, B., "The Relation Between Force and Velocity in Human Muscle," *Journal of Physiology*, 110:249-280, 1950.

65. Wilkin, Bruce M., "The Effect of Weight Training on Speed of Movement," *Research Quarterly*, 23:361-369, October, 1952.

66. Wolbers, Charles P., and Frank D. Sills, "Development of Strength in High School Boys by Static Muscle Contractions," Research Quarterly, 27:446-450, December, 1956.

67. Zorbas, William S., and Peter V. Karpovich, "The Effect of Weight Lifting Upon the Speed of Muscular Contraction," Research Quarterly, 22:145-148, May, 1951.

U.S. Office of Education
Cooperative Research Branch

Project Description

#1979 Resistive Exercises in the Development of Muscular Strength and Endurance

Lynn W. McCraw, Department of Physical and Health Education, University of Texas, Austin, Texas.
January 2, 1963 to August 31, 1963
$8,310

Objective

To analyze the effectiveness of different methods of resistive exercises as a means of increasing muscular strength and muscular endurance and of improving performance in physical activity.

Procedures

Subjects will consist of college men enrolled in physical education classes. Three groups of approximately 30 subjects each will be randomly assigned to the three programs under investigation: isotonic contraction of muscles, isometric contraction of muscles, and speed contraction of muscles.

After measurement of initial status in the attributes under consideration, subjects will engage in the appropriate resistive programs three times a week for approximately ten weeks. Measurement of final status will then be made using the same instruments as for the initial status. Attributes to be measured are strength, endurance, speed, and explosive power.

The three methods of resistance exercises will be evaluated with regard to their use in a practical situation by the following criteria: (1) time required to execute the exercises; (2) type and quantity of equipment involved; (3) cost of equipment; and (4) acceptance by students as determined by the instructor.